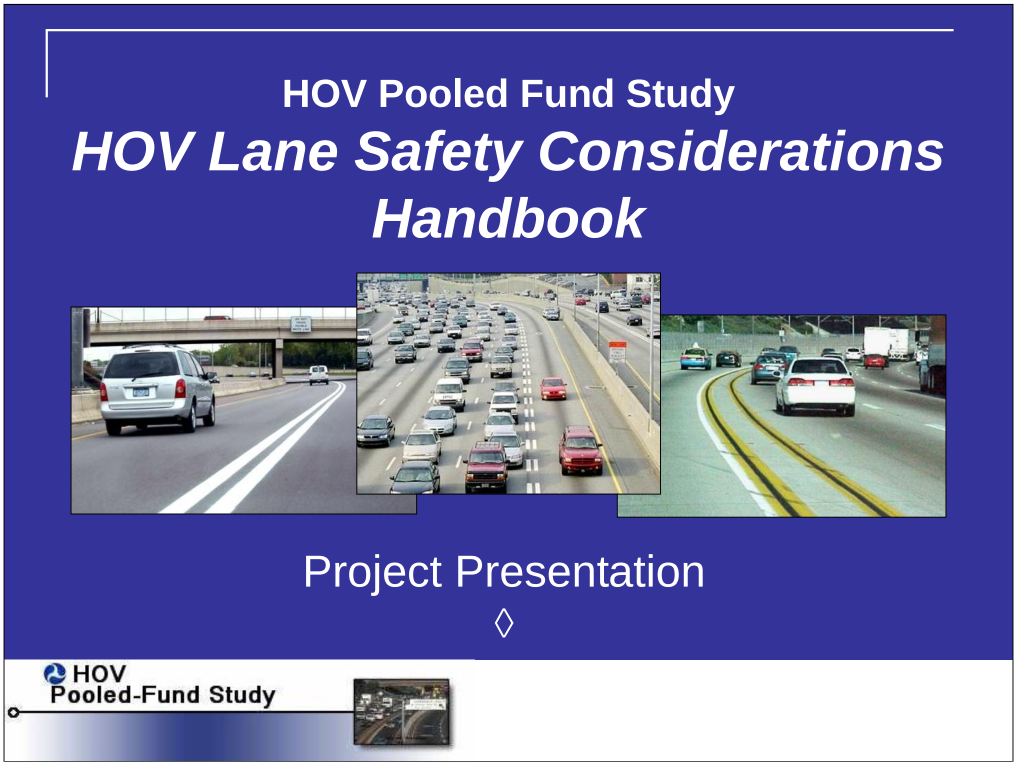
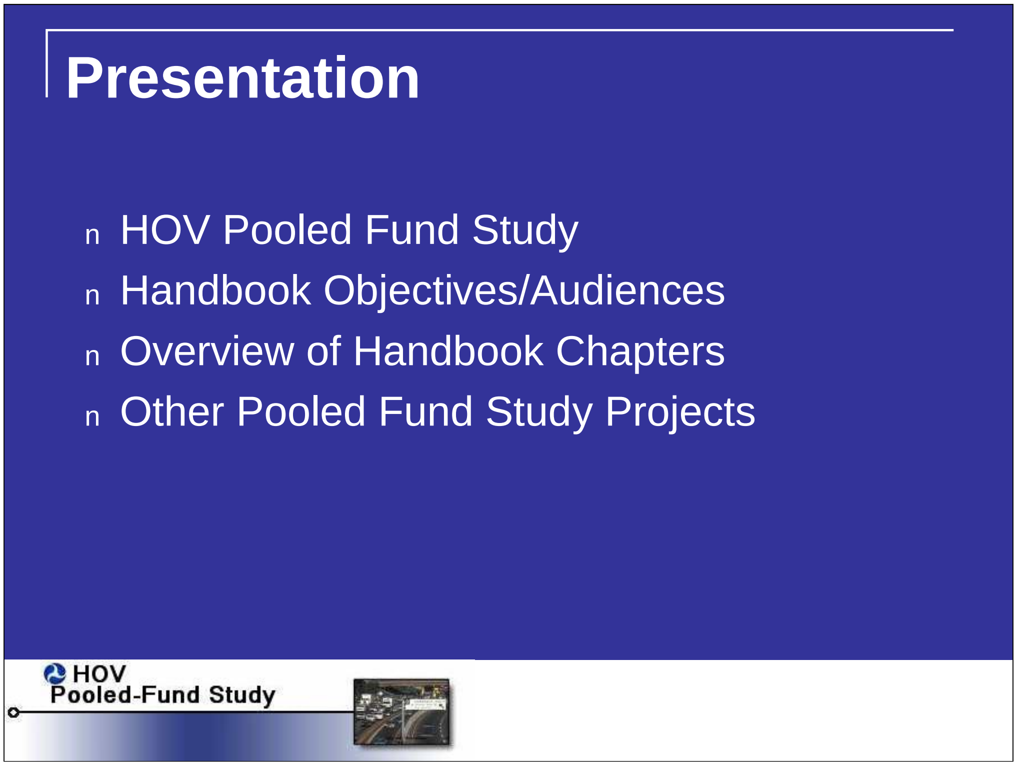
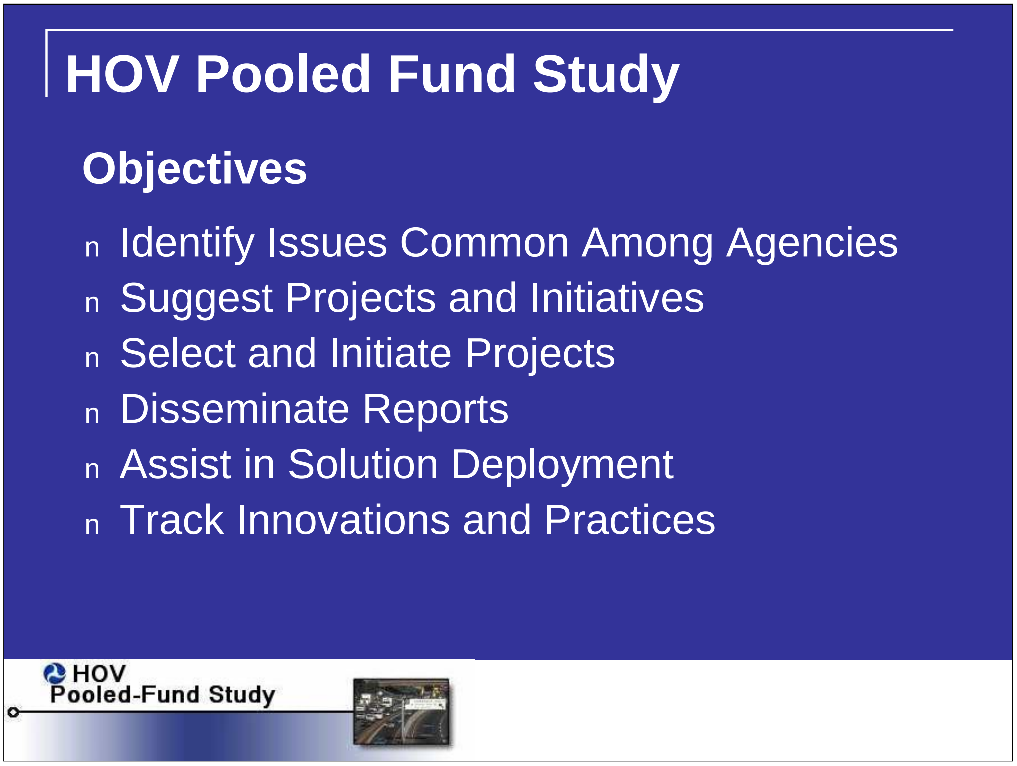


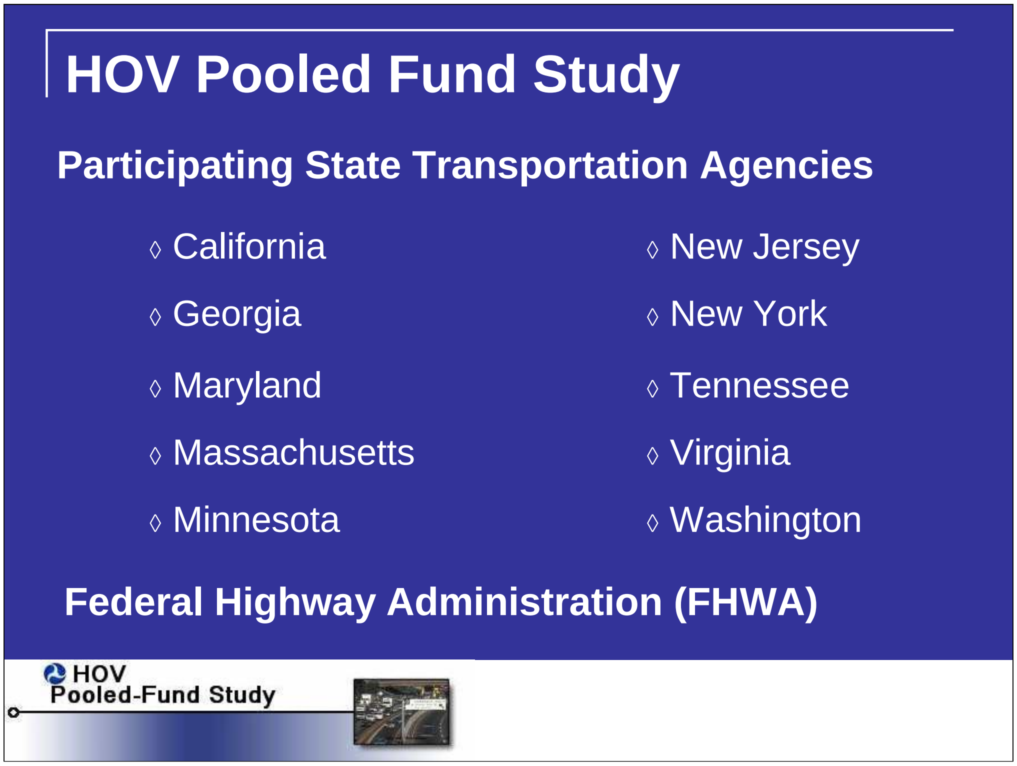
This PowerPoint presentation summarizes the High-Occupancy Vehicle (HOV) Facility Safety Considerations Handbook developed through the HOV Pooled Fund Study (PFS). It is the longer PowerPoint presentation, which highlights the key elements of the PFS project and goes through the chapters in the handbook. A shorter, less-detailed, PowerPoint presentation describing safety considerations of HOV facilities is also available.



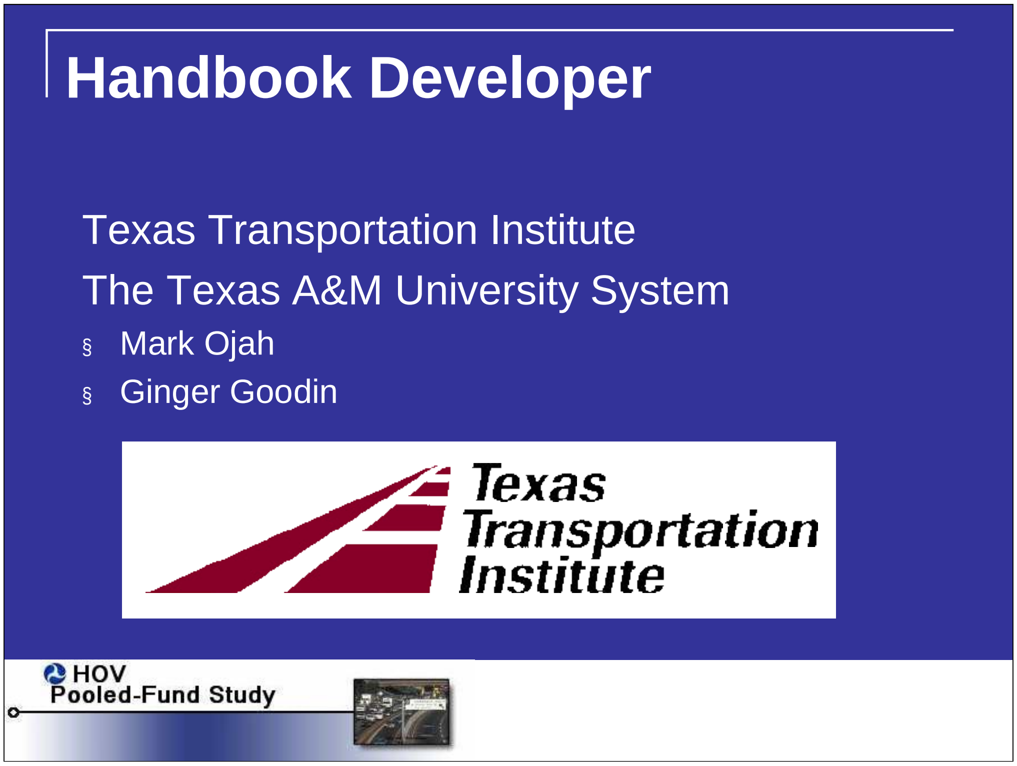
The presentation will cover four major topics. The objectives of the HOV Pooled Fund Study and the participating agencies are described first. Second, the handbook objectives are highlighted, and the audiences for the handbook and related documents are summarized. Third, the handbook chapters are summarized. The presentation concludes by highlighting other projects sponsored by the HOV Pooled Fund Study.



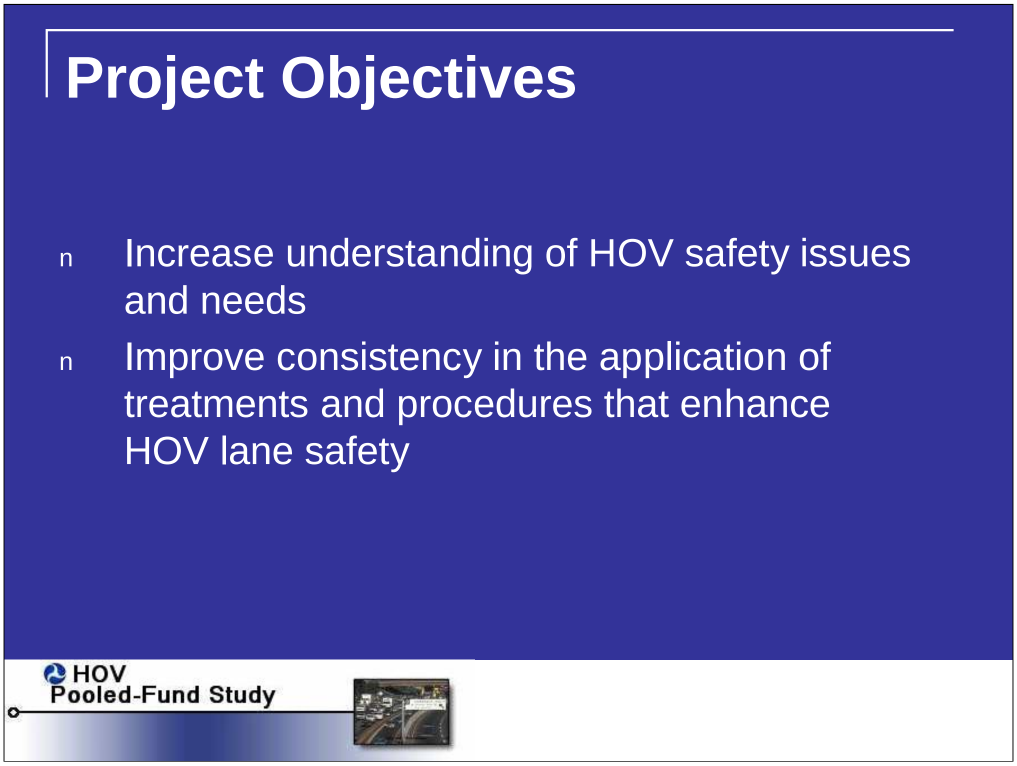
The HOV Pooled Fund Study was undertaken to accomplish a number of objectives. These objectives include identifying common issues related to HOV facilities and suggesting and selecting projects and initiatives to address these issues. Disseminating reports, handbooks, and research results, as well as assisting in solution deployment and tracking innovations and practices represent other objectives.



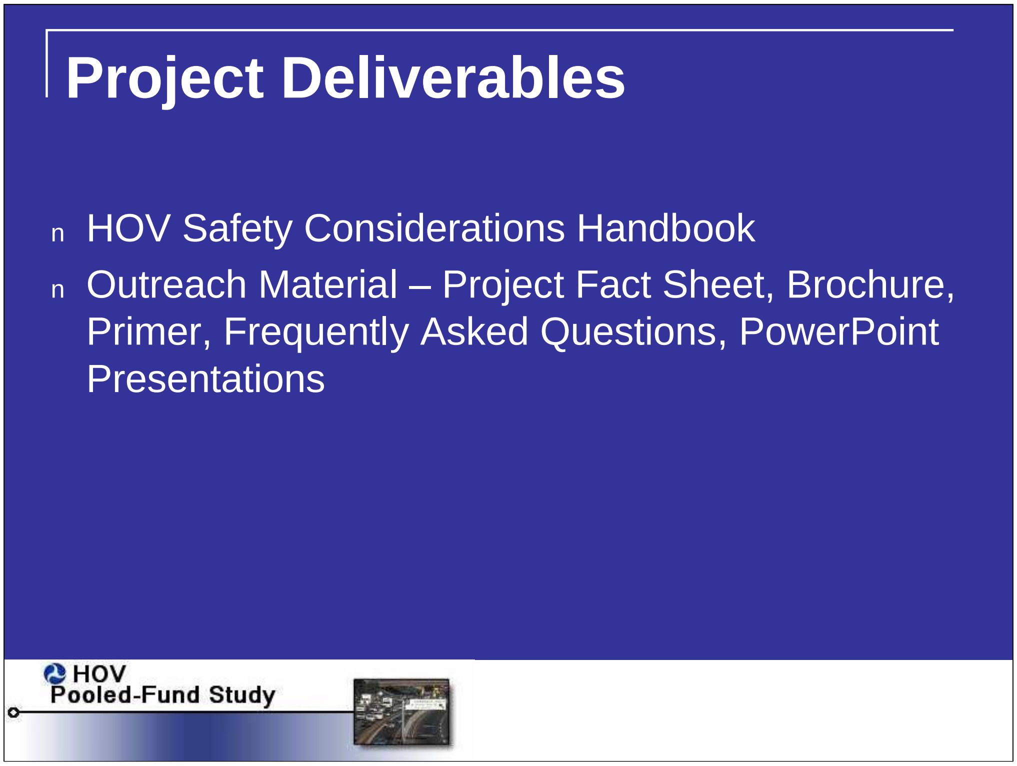
Currently, state transportation agencies in 10 states are participating in the HOV Pooled Fund Study, along with the Federal Highway Administration (FHWA). The 10 states are California, Georgia, Maryland, Massachusetts, Minnesota, New Jersey, New York, Tennessee, Virginia, and Washington. Additional state departments of transportation, public transportation agencies, and other organizations are welcome to join the HOV Pooled Fund Study. Contact information is provided at the end of the PowerPoint presentation for those interested in joining the HOV Pooled Fund Study.



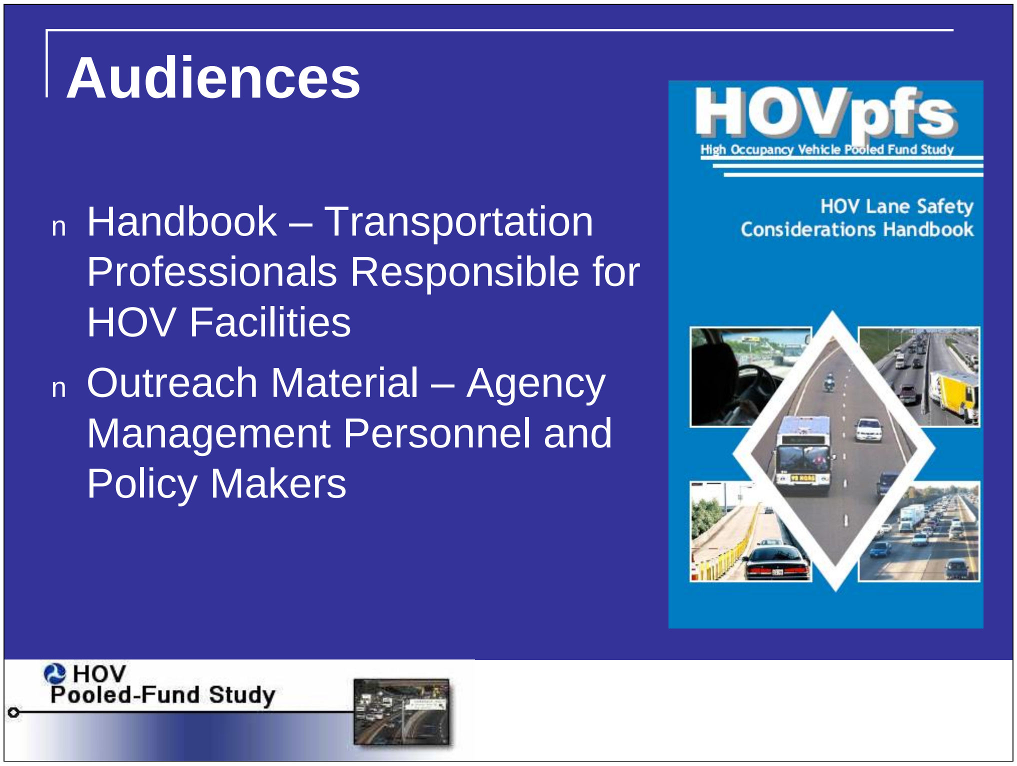
The Texas Transportation Institute (TTI), a part of The Texas A&M University System, was selected to conduct this project. Ginger Goodin served as the Principal Investigator on the project and Mark Ojah was the author of the Handbook.



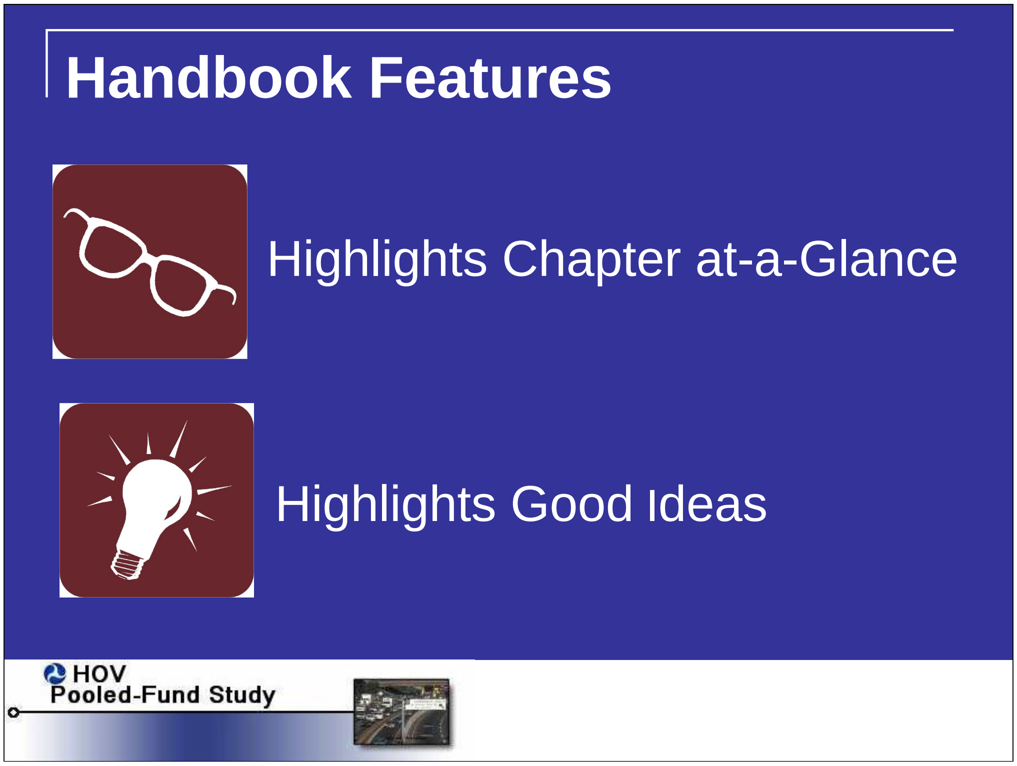
The first objective of this project is to increase understanding of HOV safety issues and needs through the planning, design and operation of HOV projects. The second objective is to advance the state-of-the-practice by improving consistency in the application of treatments and procedures that enhance safety in HOV facilities.



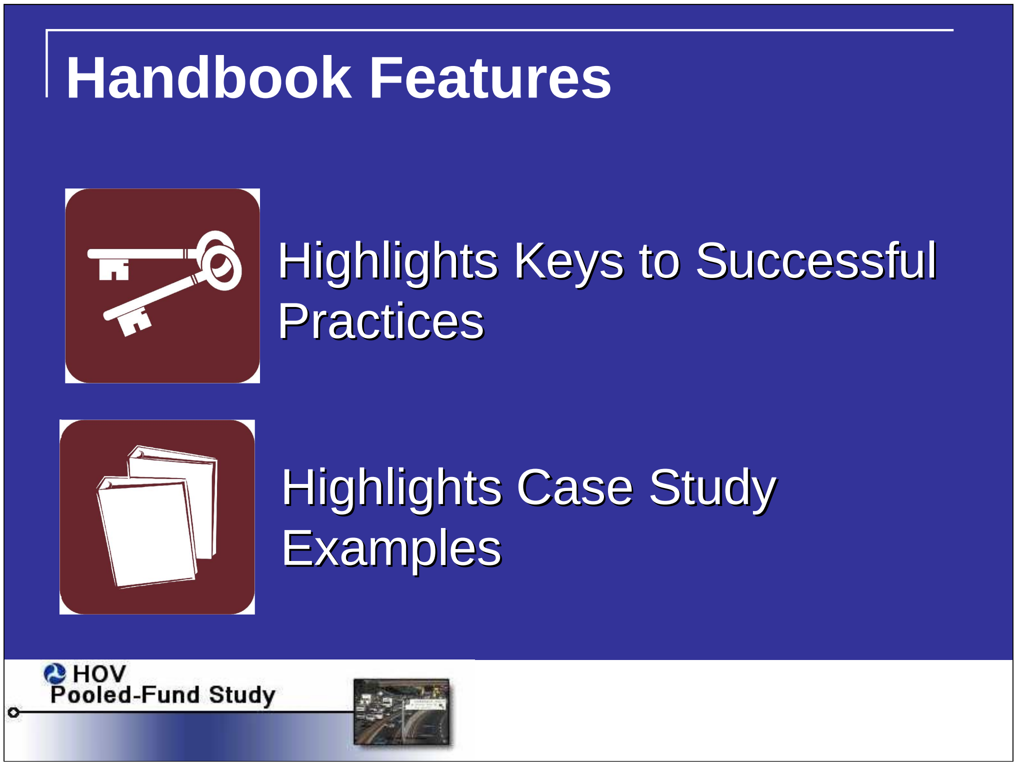
The HOV Lane Safety Considerations Handbook represents the major product from this project. Outreach materials developed through this project include a project fact sheet, a brochure, a primer, frequently asked questions, and PowerPoint presentations.



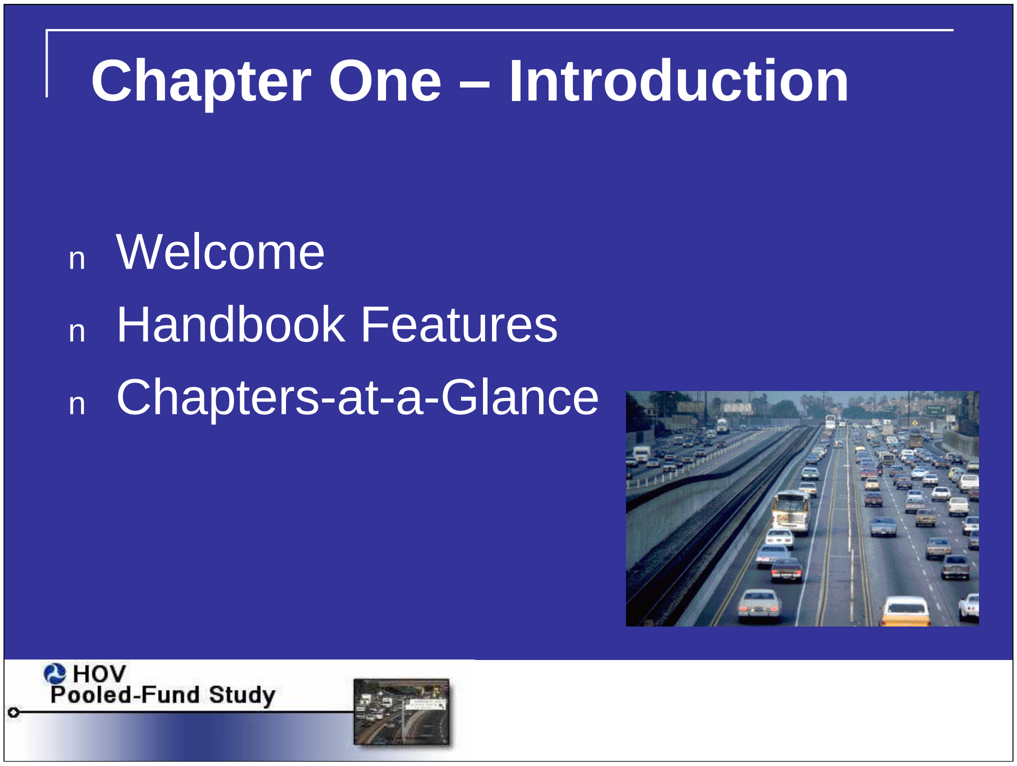
The handbook and outreach materials are targeted toward a variety of audiences and stakeholder groups. The handbook is intended for use by transportation professionals responsible for planning, designing, operating, and enforcing HOV facilities. The audiences for the outreach materials include agency management personnel and policy makers, as well as other groups interested in the performance of HOV facilities.



The handbook provides an easy to use guide to HOV safety considerations. Icons are used to highlight key points. The eyeglass icons are used to highlight the chapter-at-a-glance at the start of each chapter. The light bulb icon highlights good ideas based on best practice case studies.



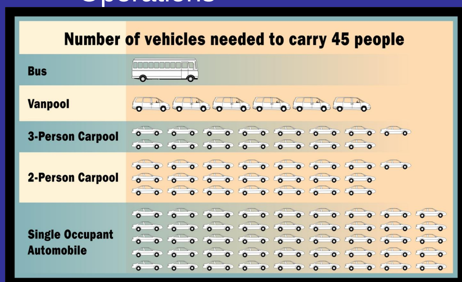
The keys icon highlights keys to successful practices. Finally, the notebooks icon highlights case study examples. The case studies in the chapters provide examples to reinforce key points. The case studies in each chapter provide more detailed descriptions of safety considerations on existing HOV facilities and expand on many of the examples in the chapters.

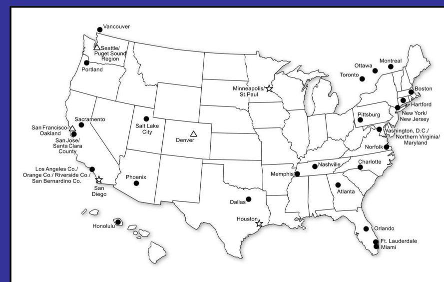


This section of the presentation describes the major topics addressed in the handbook. Chapter One presents the objectives and audiences for the handbook, highlights the use of the four icons, and summarizes the topics covered in each chapter.

Chapter Two – Overview of HOV Facilities and Safety Considerations

- Objective and Function of HOV Facilities
- HOV Facility Types
- Importance and Challenge of Addressing HOV Safety
- Key Safety Considerations in HOV Planning, Design, and Operations





HOV Pooled-Fund Study

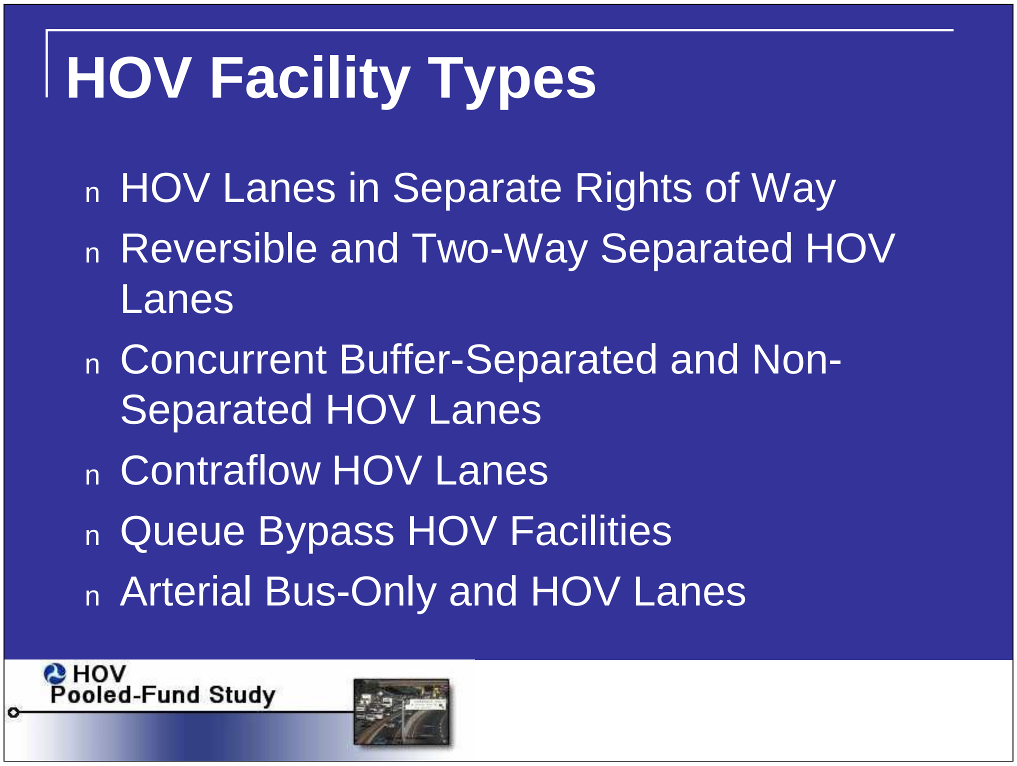
Chapter Two provides an overview of HOV facilities and highlights the key safety considerations for each phase of facility development. HOV facilities are designed and operated to provide travel time savings and trip time reliability to buses, vanpools, and carpools. Challenges to HOV safety are many, from conflicting operational goals and design priorities, to lack of crash data available for analysis by safety researchers.

Objectives and Functions of HOV Facilities

- Increase average number of occupants per vehicle
- Provide travel time savings for multi-person vehicles
- Provide more reliable and predictable travel times for multi-person vehicles
- Preserve or improve the overall person-moving capacity of the roadway
- Improve bus operations
- Reduce transportation-related fuel consumption and pollution
- Enhance transportation options
- Reduce transportation costs

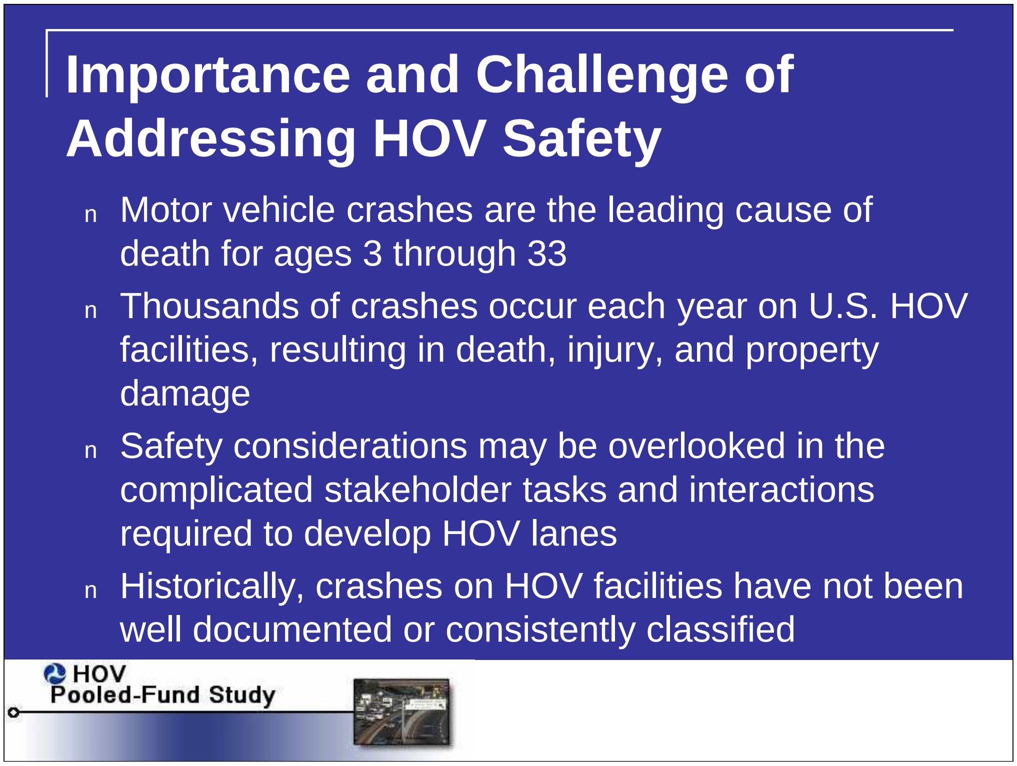
HOV
Pooled-Fund Study

HOV facilities are implemented to accomplish a number of inter-related objectives. While the stated goals of individual facilities may vary slightly according to local considerations, they often include some or all of what is listed here. HOV facilities are able to increase the person-movement capacity of congested roadways by encouraging motorists that drive alone to travel in carpools or use other multi-person transportation options such as vanpools or buses. HOV facilities accomplish this by offering occupants of multi-person vehicles the opportunity to bypass congestion on general-purpose lanes. With few exceptions, single-occupant vehicles are prohibited from traveling on HOV facilities and most require that eligible vehicles carry a minimum of two or three occupants. Not only do HOV facilities provide benefits for those that ride-share, they also provide an incentive for single-occupant vehicles by allowing them to see the time-saving advantages available to those who travel together.

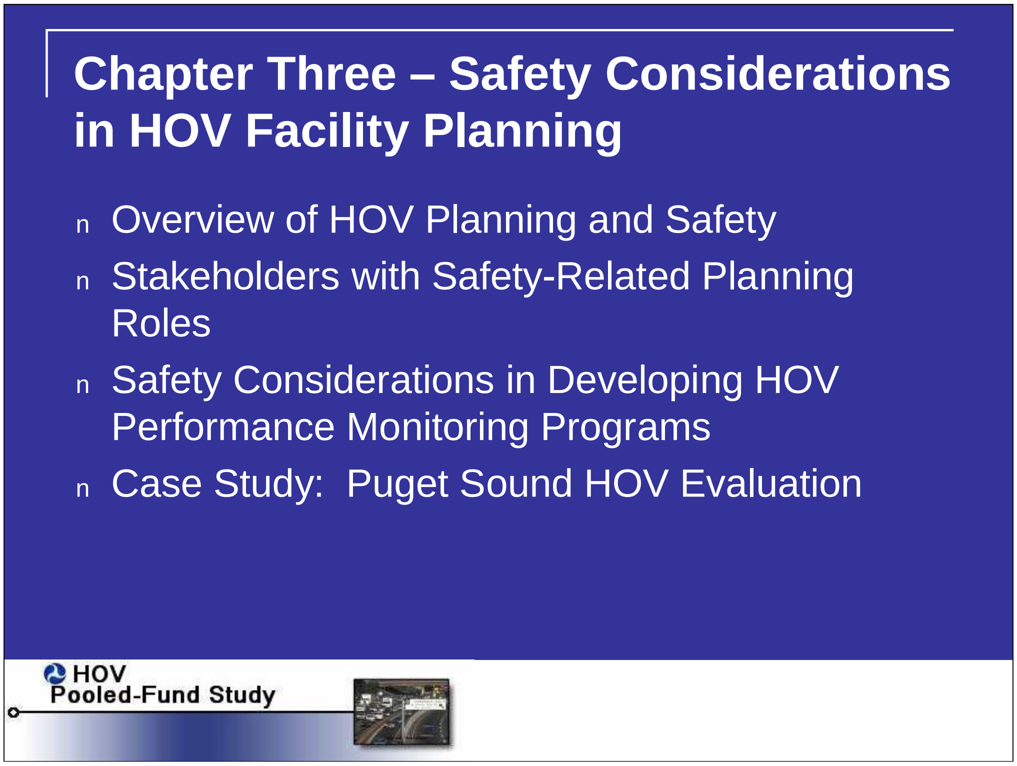


HOV facilities are broadly grouped according to their application on freeways or arterial streets. These are some of the most common types of HOV facilities in the United States:

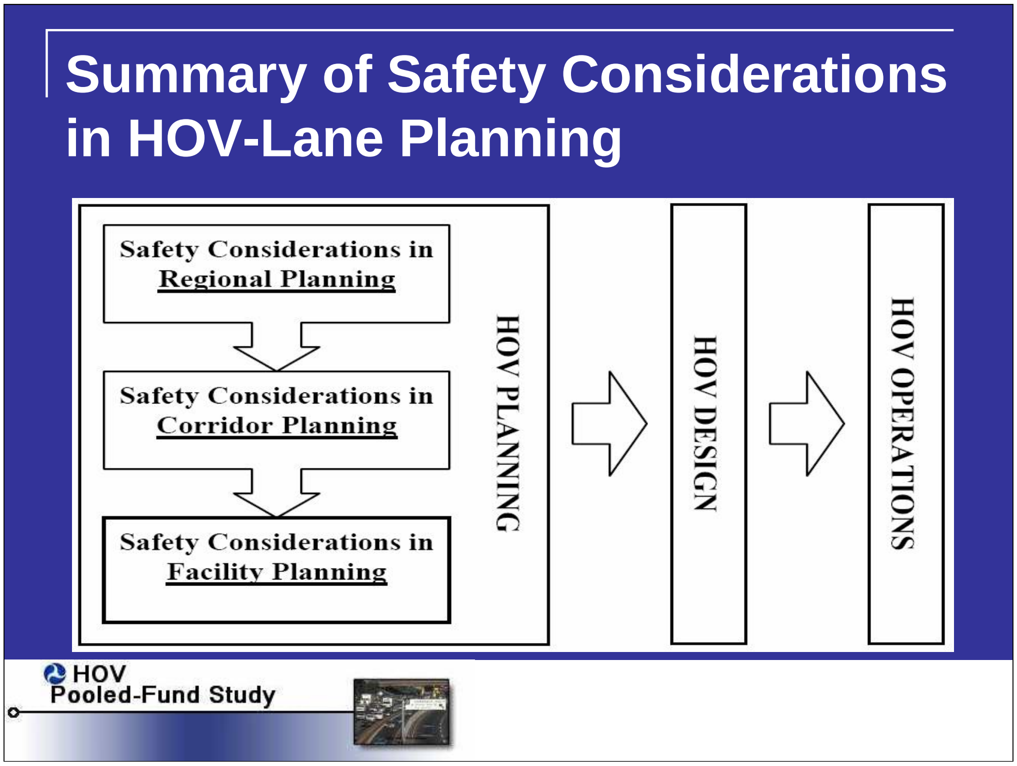
- HOV lanes located in separate rights of way are physically isolated from the freeway general-purpose lanes.
- Reversible and two-way barrier-separated HOV lanes are located within the freeway right of way, are generally constructed in the median, are physically separated from the general-purpose lanes by permanent concrete barriers, and are open to a broad range of high-occupancy vehicles. They are usually characterized by one or two reversible lanes that operate in the peak-period direction of travel.
- Concurrent HOV lanes are facilities that operate in the same direction as the adjacent general-purpose lanes and are not physically separated from them. These types of facilities are either separated from the general-purpose lanes by a buffer or are non-separated; buffer-separated facilities can be further classified as limited-access, meaning that vehicles may only enter/exit the HOV lane at designated access points, or unlimited access.
- Contraflow HOV lanes are located within the freeway right-of-way and divert traffic traveling in the peak direction into a designated lane in the off-peak direction separated by concrete barriers or plastic pylons.
- Queue bypass facilities are designed to enable high-occupancy vehicles to circumvent congestion at a specific location such as a freeway ramp meter. HOVs are either granted unimpeded access to the freeway or are metered at a preferential rate over non-HOV traffic.
- The functions of arterial HOV lanes mirror those of their freeway counterparts, except that they serve short trips, operate at slower speeds, provide access to local streets, and may be open to bicycle traffic.



Chapter 2 highlights the importance of addressing HOV safety and identifies some of the challenges which make it difficult to implement safety considerations into HOV design. Motor vehicle crash rates have declined for decades, but data indicate that the rate at which motor vehicle crashes are decreasing has slowed in recent years. HOV networks, whose operations are affected by congestion and can present complex driving situations to motorists underscore the importance of continued analysis and improvement of road safety techniques. Reducing crashes on HOV facilities entails the identification and integration of safety practices into HOV-lane planning, design, and operations. Safety considerations can easily be diluted or overlooked due to the fact that such a large number of entities are involved in the planning, design, construction, operation, and maintenance of HOV facilities. HOV-lane safety analysis has historically been poorly executed and has produced inconclusive or contradictory findings with respect to the safety of specific HOV-lane policies and treatments. Developing an understanding of the factors affecting HOV safety is an important and challenging task.

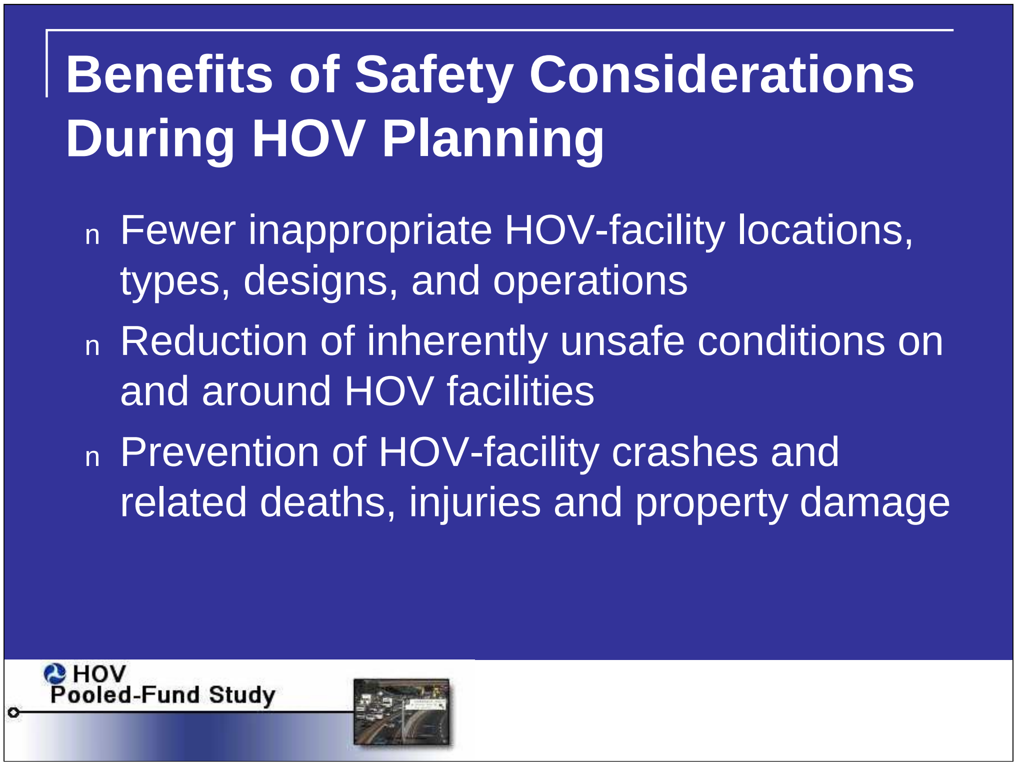


HOV-facility safety begins with the planning process. Chapter Three offers an overview of the relationship between HOV planning and safety and an explanation of regional, corridor, and facility-planning efforts. The broad safety responsibilities of stakeholders engaged in HOV planning are presented, followed by an examination of safety-related performance monitoring activities to be initiated during the HOV planning stage. This chapter provides a context for the issues presented in the following chapters on facility design and operation.



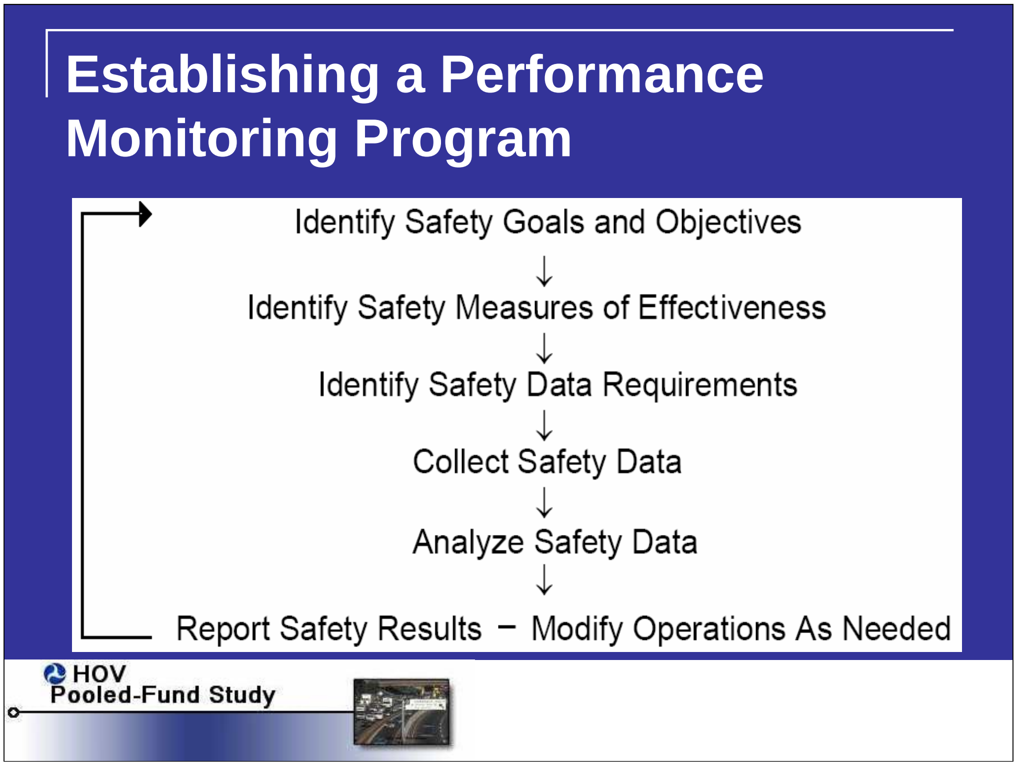
Chapter 3 begins by stressing the importance of incorporating safety considerations into the planning stage of HOV-facility development. The incorporation of safety considerations into the HOV-planning process has subsequent impacts on HOV design and operations, as illustrated by this schematic. The extent of the planning process depends upon a number of factors but is generally commensurate with project complexity.

Integrating safety into the planning process makes safety issues more salient among the project stakeholders and promotes a proactive approach to facility safety in subsequent phases of project development.



Safety considerations during the HOV-facility planning process can have profound effects on the success of the project. The attention paid to safety during the planning process will carry through the entire project. Safety awareness during this crucial process can reduce the number of inappropriate HOV-facility locations, types, and designs that would otherwise cause problems for HOV-lane operations. Consequently, potentially unsafe conditions are avoided and fatalities, injuries, crashes and property damage associated with HOV facilities are prevented.

It is important to identify and involve all relevant stakeholders during the HOV-facility design stage. The input received from each of these diverse entities will help ensure that pertinent knowledge and perspectives are taken into account during project development. The project's safety and security may be jeopardized by overlooking key stakeholders during the design process. For example, failure to include local law enforcement in HOV planning could lead to the selection of a facility that is inherently difficult to enforce. This could allow for excessive violation leading to higher crash rates, create significant public opposition, and contribute to the demise of the project. The composition of HOV planning teams will vary depending on the scope and nature of the project. It is important to note that there may be additional stakeholders not listed here that have safety-related responsibilities in HOV planning.



Performance monitoring programs are implemented to determine whether or not HOV projects are achieving objectives and incorporating safety goals into facility development plans. This slide illustrates the main steps involved in developing and conducting an HOV performance monitoring program as it pertains to safety. Identification of safety related goals and objectives is the first step in performance monitoring. The safety goals are succinct statements that serve to identify safety as a project priority and advance safety issues throughout HOV development. Each goal may have one or more measures of effectiveness which provide a means for undertaking quantitative safety analysis. These measures should be precise and focus on the core elements of their respective goals. The identification of safety data requirements flows directly from the previous step. Data requirements for each measure of effectiveness should be unambiguous and the method of collecting and analyzing the data should be clear. Safety data must be collected for two or three years prior to HOV-facility construction, be maintained throughout the design and construction phase, and continue on an ongoing basis once the facility has opened. Analysis and reporting of safety data are conducted on an ongoing basis throughout project planning and implementation.

Case Study

- Puget Sound HOV Evaluation
  - Washington DOT wanted to determine safety impact of removing occupancy restrictions on facilities during nights and weekends
  - Determined that growth in HOV traffic would increase probability of crashes
  - Mitigation techniques implemented to improve safety before opening up facilities to general-purpose traffic

HOV
Pooled-Fund Study

• Washing State Department of Transportation wanted to determine the safety impact of removing occupancy restrictions on HOV facilities during nights and weekends.

• Found that doing so would have negligible safety impact as long as direct access ramps continued to be restricted

• But, growth in HOV traffic would increase probability of crashes.

• To address concern, mitigation techniques were identified and implemented before general-purpose traffic was permitted on the lanes.

They included:

•installation of shoulder rumble strips,

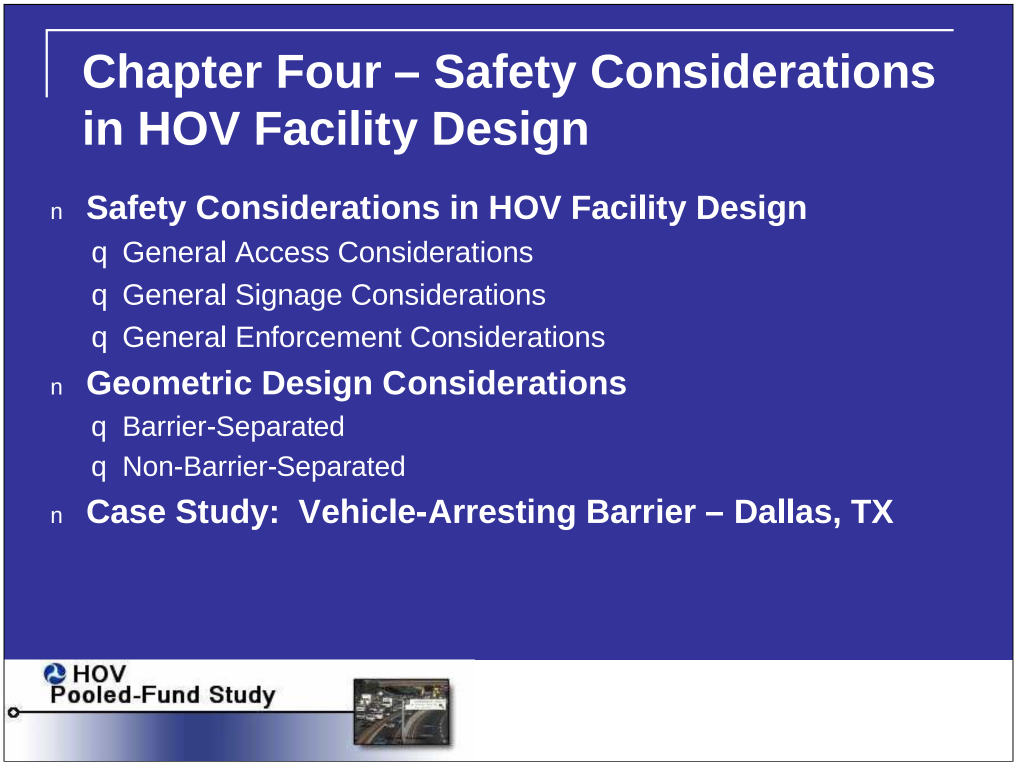
•improved striping,

•raised profile edge lines,

•additional guardrails and median barriers, and

•improved signage.

• These improvements aimed to improve safety on HOV facilities during HOV and non-HOV periods.



The design-related safety considerations in Chapter 4 build on the safety planning information presented in Chapter 3. General design considerations relative to access, signage, and enforcement are reviewed with particular emphasis on safety performance. A review of geometric design standards prescribed in the AASHTO Guide for High-Occupancy Vehicle Facilities is provided, and potential safety implications are explained for both barrier and non-barrier separated facilities.

General Access Considerations

- Apply locally recognized entrance and exit standards
- Consider sight distance and safety lighting
- The location of ingress/egress facilities should be strategically positioned
- HOV lane should be located out of the normal path of travel
- Access ramps should provide adequate space for possible metering and storage
- Provisions should be made so that ramps can be safely added later
- HOV lane drops should be avoided
- Weave analysis should be performed

HOV
Pooled-Fund Study

Ingress and egress treatments, the design features that enable vehicles to enter and exit limited-access HOV lanes, are fundamental to the design of HOV lanes and can have a significant effect on vehicle conflicts. This section of the handbook references some general safety-related considerations which pertain to HOV ingress and egress design, and includes the following highlights:

- The same geometric criteria should be applied as would be used for a freeway ramp, including recognizable entrance and exit standards.
- Sight distance is a concern due to the proximity of barriers to ramp-lane alignments and minimal lateral clearances from the edge of the travel lane to the barrier. These same factors warrant that sufficient safety lighting be applied for all access locations.
- The location of access facilities should be strategically positioned so as to prevent significant weaving conflicts.
- Motorists desiring access onto or out of the HOV facility from a freeway lane should be required to make an overt maneuver so as to ensure that HOV through traffic is not inadvertently exited.
- HOV-lane access ramps should be able to accommodate possible metering and storage facilities and provisions should be made so that direct or elevated ramps can be safely added later.
- HOV lane drops should be approached with caution due to the high speed differential between HOV-lane traffic and general travel lanes.
- Weave analysis should be performed to ensure that the selected access design can accommodate existing and projected traffic volumes.

General Signage Considerations

- Adequate advance signage and pavement markings should be used
- Design signs to adhere to MUTCD standards
- Sign size should be consistent with speed of traffic reading it
- Ensure information is presented consistently
- Use diamond symbol to mark pavement

HOV
Pooled-Fund Study

HOV-lane signage, pavement markings, and other traffic control devices, perform an important safety function by providing travelers with information that is necessary for safe use of the facility. The handbook outlines the following guidelines that should be observed to minimize/prevent signage-related confusion:

- Advance signage and clear pavement markings should emphasize HOV-lane designation
- Standard MUTCD white diamond symbol should be used and guidelines for color, font and type size should be followed to make signs easily identifiable
- The speed of traffic should be considered when determining the size of the signs
- Identify the lane on the top line of the sign, who it applies to on the second line, and applicable time of day and day of week on the last line and be consistent about where signs are placed
- Diamond symbol should be used to mark the pavement on ALL HOV lanes, and symbols should be repainted as needed

Enforcement Attributes Associated With HOV-facility Design

Type of HOV Lane	Preferred Enforcement Attributes	Minimum Enforcement Attributes
Barrier-Separated (Two-way and Reversible)	• Enforcement areas at entrances exits	• Enforcement areas at entrances or exits
Concurrent Flow	• Continuous enforcement shoulders with periodic barrier offsets • Continuous right-side shoulders	• Periodic mainline enforcement areas • Monitoring areas • Continuous right-side shoulders
Contraflow	• Enforcement area at entrance • Continuous shoulder for enforcement	• Enforcement area at entrance
Queue Bypass	• Enforcement area on right-side shoulder • Continuous right-side shoulder • Duplicate signal head facing enforcement area at ramp meters	• Enforcement monitoring pad with continuous right-side shoulder downstream

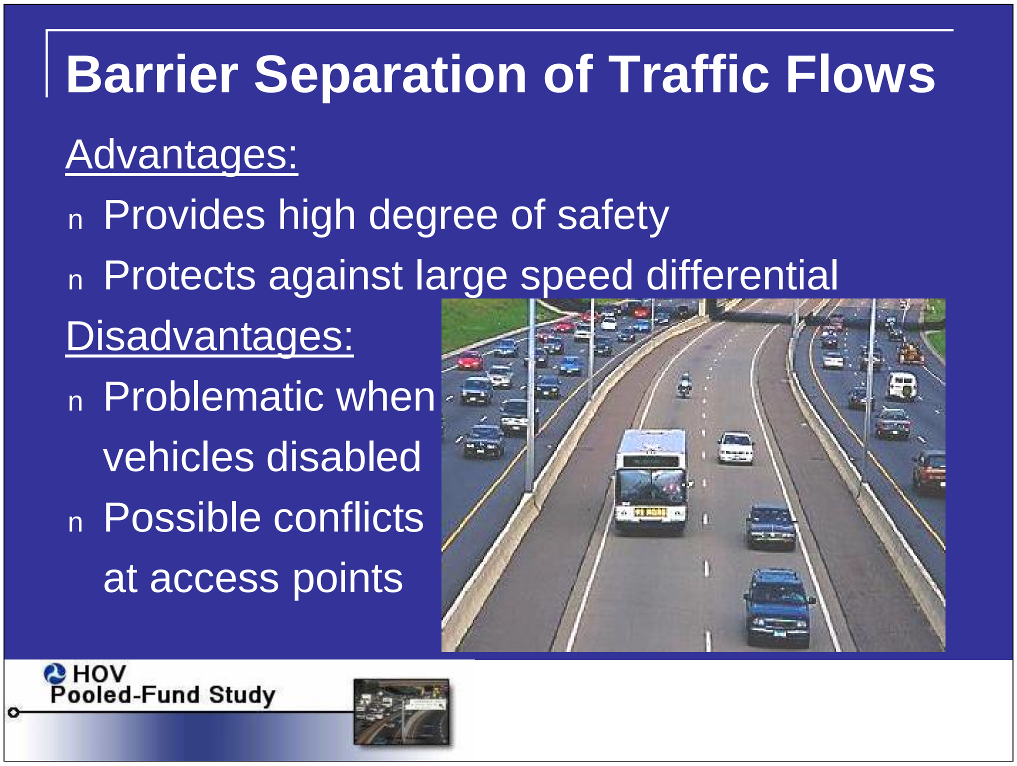
HOV
Pooled-Fund Study

Enforcement is an important component of HOV-lane design and operations and can have a significant impact on the success and viability of an HOV project. This table illustrates how various HOV-facility designs require unique enforcement considerations and emphasizes the importance of consulting enforcement personnel and agencies in the facility design process. It may become evident upon further investigation of enforcement associated with the chosen design that additional lighting , signage, and traffic control devices are required to allow for smoother, safer enforcement and facility operations. The design should provide space for law enforcement personnel to monitor an HOV facility, pursue and safely pull over violators, and issue a ticket or citation. The minimum width of these enforcement areas should be between 12 and 14 ft. and they should be at least 100 ft long.

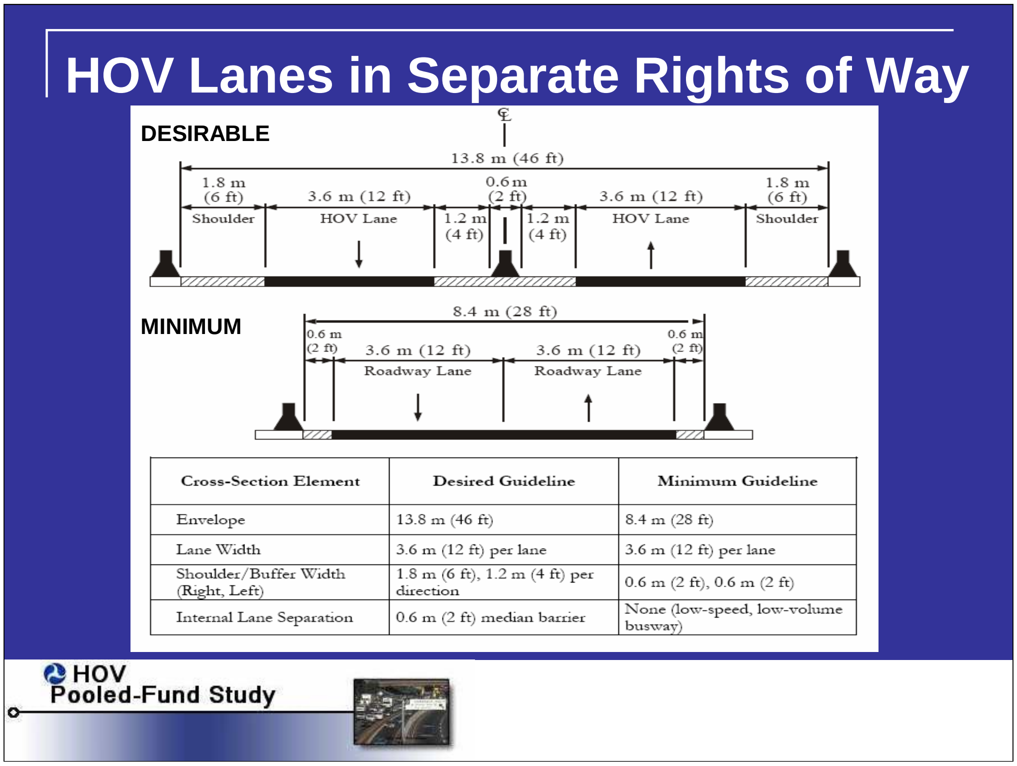
Geometric Design: Barrier-Separated Facilities

Safety Considerations

HOV Pooled-Fund Study



Each of the various geometric design considerations for an HOV-facility has a unique set of safety implications associated with it. The decision to use a barrier to separate the HOV facility from the rest of traffic carries some safety advantages and disadvantages. The most obvious advantage is that barrier separated HOV-lanes provide a high degree of protection for both those that use the facility and those who are in adjoining lanes. Collisions that occur in the general purpose lanes do not typically affect the operation of the barrier-separated facility and the barriers prevent frequent crossover of vehicles into and out of the facility. Also, barrier-separated HOV facilities protect against the large speed differential that usually exists between traffic in the HOV-lanes and the slower moving traffic in the general-purpose lanes. Even though it is generally agreed upon that barrier-separated facilities are safer than non-barrier facilities, there exists potentially significant safety hazards associated with barrier-separated traffic flows. Barrier-separated HOV lanes have many of the characteristics of a tunnel because once on the lane, vehicles must travel to the next access point before exiting. Therefore, any incidents occurring in these sections can interfere with traffic flow if shoulder widths are insufficient to allow traffic to safely bypass disabled vehicles. Barrier-separated HOV lanes are also considerably more costly because they require a wider right-of-way and involve the construction of special access points to allow traffic to move into and out of the facility. The location and design of at-grade access points should be carefully considered in relation to freeway interchanges so that vehicles have sufficient room to safely enter or exit the facility. Access points on barrier-separated HOV lanes should concentrate weaving where capacity exists and adequate merge/weave zones can be implemented.



Cross-Section Element	Desired Guideline	Minimum Guideline
Envelope	13.8 m (46 ft)	8.4 m (28 ft)
Lane Width	3.6 m (12 ft) per lane	3.6 m (12 ft) per lane
Shoulder/Buffer Width (Right, Left)	1.8 m (6 ft), 1.2 m (4 ft) per direction	0.6 m (2 ft), 0.6 m (2 ft)
Internal Lane Separation	0.6 m (2 ft) median barrier	None (low-speed, low-volume busway)

Freeway HOV lanes in separate rights-of-way are physically isolated from general purpose lanes. They are typically designed for the exclusive use of buses; operate as two-lane, two-directional facilities; and present relatively few safety issues. As illustrated in this schematic, the design envelope required for safe operation of this facility type varies from 13.8 m (46 ft) to a minimum of 8.4 m (28 ft). A concrete median barrier is recommended for separating opposing traffic flows on facilities that are open to carpools and vanpools. The desirable cross section, as shown on top, includes travel-lane widths of 3.6 m (12 ft), shoulder widths of 1.8 m (6 ft), and lateral clearances of 1.2 m (4 ft) to the median barrier. This cross section enables vehicles traveling at low speeds to pass a disabled bus. Virtually all U.S. HOV lanes in separate rights-of-way serve buses only and have been designed with a median consisting of a solid double yellow line. This and other minimum design features such as lateral clearances of 0.6 m (2 ft) to barriers should only be considered on exclusive busways that are characterized by low-speed, low volume operations.

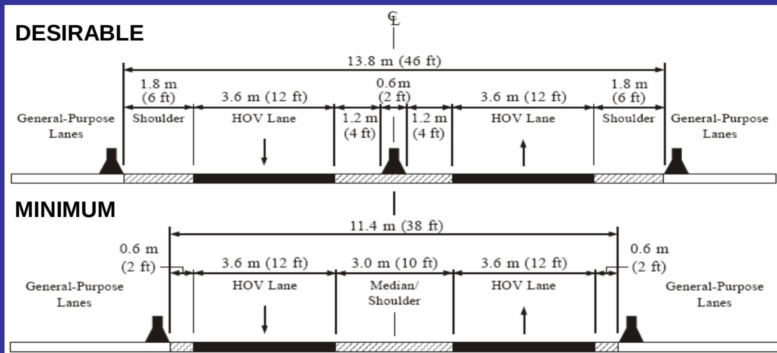
Access and Enforcement Treatments for HOV Lanes in Separate Rights of Way

- Access locations should incorporate restrictive traffic control devices to prevent wrong-way movements
- Use of highly-visible crash cushions can attenuate number and severity of barrier-end collisions
- Ingress points should be clearly signed with respect to vehicle eligibility and hours of operation regulations to prevent illegal/unsafe entry

HOV
Pooled-Fund Study

HOV lanes in separate rights-of-way usually offer a limited number of access points to and from park-and-ride lots and local streets. Access locations should incorporate restrictive traffic control devices such as gates, barricades, flashing beacons, and no-entry signs (as appropriate) to prevent wrong-way movements. The number and severity of barrier-end collisions at access points can be attenuated through the use of highly-visible crash cushions. Ingress points should be clearly signed with respect to vehicle eligibility and hours-of-operation regulations to prevent illegal or unsafe entry. Ineligible vehicles such as cars and vans are easily spotted on exclusive busways. Transit drivers are therefore generally relied upon to report violators, who can then be intercepted at facility egress points.

Two-Way Barrier-Separated HOV Lanes



Cross-Section Element	Desired Guideline	Minimum Guideline
Envelope	13.8 m (46 ft)	11.4 m (38 ft)
Lane Width	3.6 m (12 ft) per lane	3.6 m (12 ft) per lane
Shoulder/Buffer Width (Right, Left)	1.8 m (6 ft), 0.6 m (2 ft) per direction	0.6 m (2 ft) per direction, 3 m (10 ft) shared buffer/shoulder
Internal Lane Separation	0.6 m (2 ft) median barrier	Median buffer (see above)

HOV
Pooled-Fund Study

Two-way barrier-separated HOV lanes are located within the freeway right of way, permit simultaneous travel in both directions, and are physically separated from the general-purpose lanes by concrete barriers. As shown in the schematic, the desirable design envelope for safe operations of this type of facility is 13.8 m (46 ft). Minimum facility width is 11.4 m (38 ft). Both minimum and desirable designs include standard lane widths of 3.6 m (12 ft). A concrete median barrier should be incorporated into the design if the facility is intended to accommodate carpools and vanpools operating at high speeds. This prevents head-on collisions if a vehicle loses control in the lane. Minimum lateral clearance of 0.6 m (2 ft) to the median barrier is required to reduce inadvertent vehicle-barrier contact, and an offset of 1.2 m (4 ft) desirable for increased safety. Decisions regarding the precise lateral offset should be coordinated with other safety-related design considerations such as sight distances, design speed, and signage. Where the use of a median barrier is not feasible, a shared 3.0 m (10 ft) non-raised median shoulder may be used. In such cases, passing should be prohibited and cross hatching or other delineation should be employed. The shared median minimum cross section should only be used for two-way ramps, short connector section, low-volume HOV lanes, or other lower speed facilities.

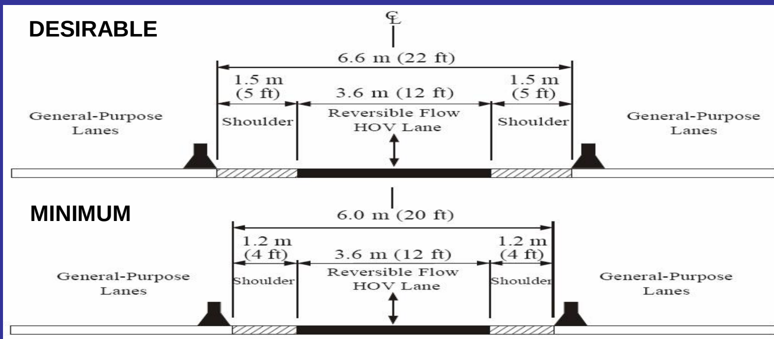
Prioritized Design Trade-offs for Two-Way Barrier Separated HOV Lanes

Ordered Sequence	Cross-Section Design Change
First	Reduce HOV envelope to 12.6 m (42 ft) according to the middle schematic with 0.6 m (2 ft) offset to middle barrier.
Second	Reduce freeway left lateral clearance to no less than 0.6 m (2 ft).
Third	Reduce freeway right lateral clearance (shoulder) from 3.0 m (10 ft) to 2.4 m (8 ft).
Fourth	Reduce HOV-lane width to no less than 3.3 m (11 ft) (some agencies may prefer reversing the fourth and fifth tradeoffs when buses or trucks are projected to use the HOV lane).
Fifth	Reduce selected general-purpose lane widths to no less than 3.3 m (11 ft) (leave at least one 3.6 m [12 ft] outside lane for trucks).
Sixth	Reduce freeway right lateral clearance (shoulder) from 2.4 m (8 ft) to 1.2 m (4 ft).
Seventh	Convert barrier shape at columns to a vertical face.

HOV
Pooled-Fund Study

Proper consideration of safety in HOV-facility design entails full examination of potential alternatives to design compromises. However, if the HOV lane is a retrofit design being implemented in a constrained right of way, the use of minimum design standards or exceptions may be acceptable. Decisions to adopt facility designs that do not meet full AASHTO standards should be carefully scrutinized by project stakeholders with safety being the foremost consideration. An engineering safety review should be undertaken to determine the potential safety impact of any design compromises adopted. This table presents a prioritized list of design tradeoffs that may be considered for two-way barrier-separated HOV facilities that cannot be constructed to desirable design standards. The ordered sequence presented here is only an example list. Some states may prefer a different sequence.

Single Lane Reversible Barrier-Separated HOV Lanes

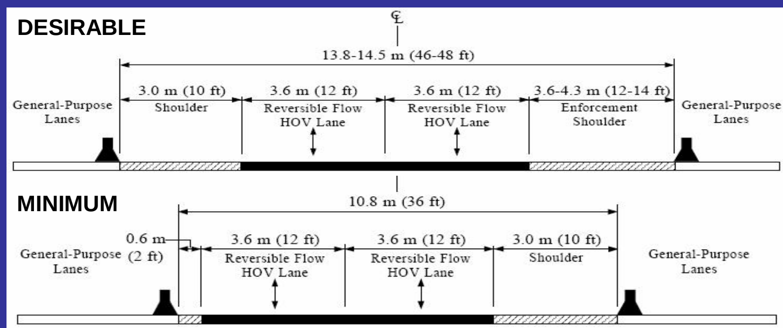


Cross-Section Element	Desired Guideline	Minimum Guideline
Envelope	6.6 m (22 ft)	6.0 m (20 ft)
Lane Width	3.6 m (12 ft)	3.6 m (12 ft)
Shoulder/Buffer Width (Right, Left)	1.5 m (5 ft), 1.5 m (5 ft)	1.2 m (4 ft), 1.2 m (4 ft)
Internal Lane Separation	N/A	N/A

HOV Pooled-Fund Study

Single-lane reversible barrier-separated HOV facilities are located within the freeway right of way, offer one lane of travel in the peak direction, and are physically separated from the general-purpose lanes by concrete barriers. Figure 4-3 shows desirable and minimum cross sections for this type of facility. The desirable design calls for an envelope of 6.6 m (22 ft), while the minimum design can be accommodated in a 6.0 m (20 ft) envelope. Standard 3.6 m (12 ft) lane widths of should be used. Desirable and minimum lateral clearances are 1.5 m (5 ft) and 1.2 m (4 ft) respectively. The even distribution of clearances on either side of the travel lane enhances safety by discouraging passing. This design also provides for the largest barrier offset in both directions, while permitting motorists to maneuver around disabled vehicles that are parked to one side of the facility. A general summary of the cross-section guidelines for a single-lane reversible barrier-separated HOV facility is provided in Table 4-6.

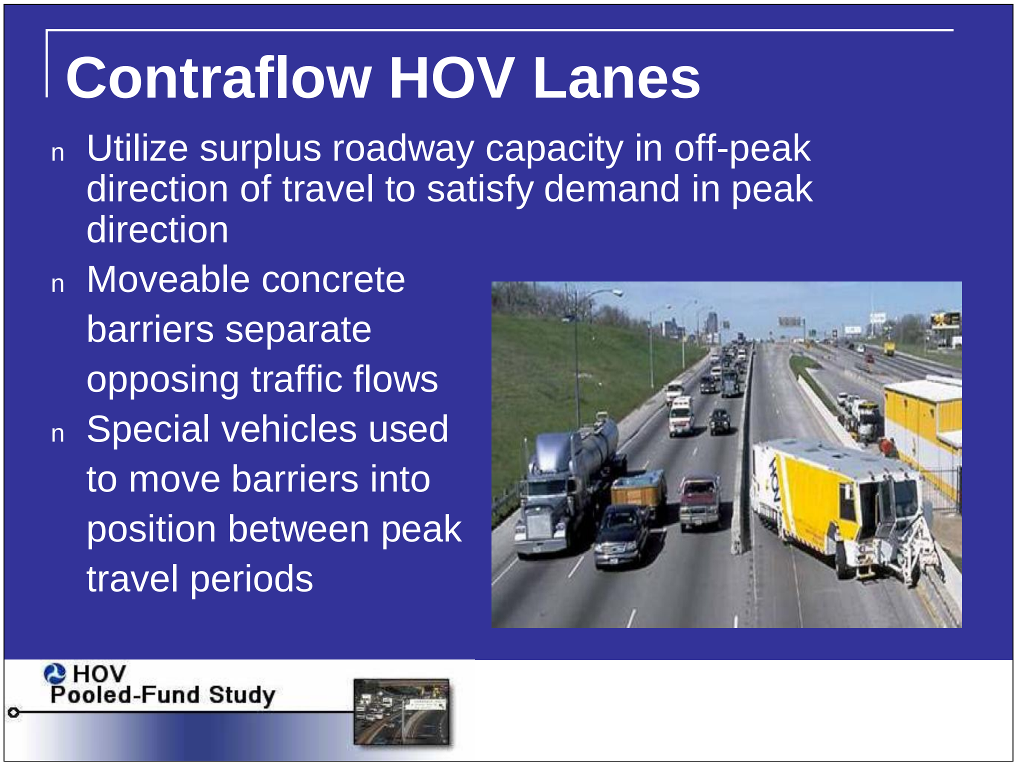
Two Lane Reversible Barrier-Separated HOV Lanes



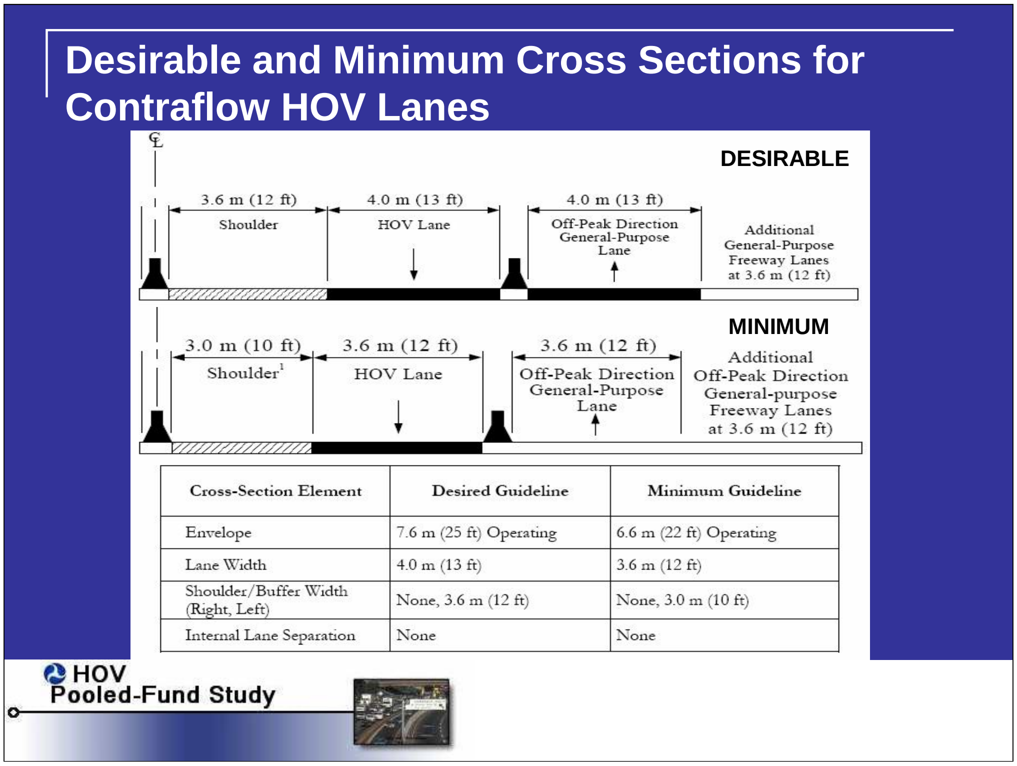
Cross-Section Element	Desired Guideline	Minimum Guideline
Envelope	13.2 to 14.5 m (44 to 48 ft)	10.8 m (36 ft)
Lane Width	3.6 m (12 ft) per lane	3.6 m (12 ft) per lane
Shoulder/Buffer Width (Right, Left)	3.0 to 4.3 m (10 to 14 ft) Depends on the use of enforcement shoulder, 3.0 m (10 ft)	3.0 m (10 ft), 0.6 m (2 ft)
Internal Lane Separation	None	None

HOV Pooled-Fund Study

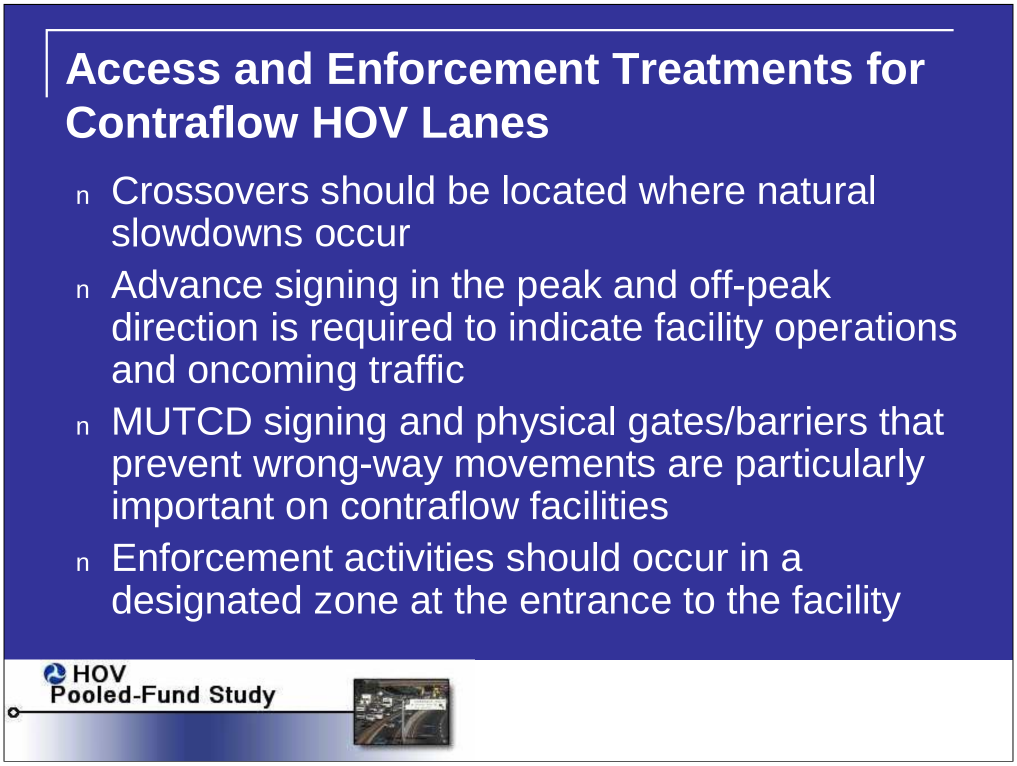
Apart from the number of lanes offered, the primary design difference between single and two-lane reversible barrier-separated HOV facilities is the width of their shoulders. Desired and minimum design envelopes required for a two-lane facility are shown in the schematic. An envelope of 13.8 to 14.5 m (46 to 48 ft) is needed to incorporate a full shoulder on one side and an enforcement shoulder on the other. The minimum design can be accommodated in an envelope of 10.8 m (36 ft). This design includes a 3.0 m (10 ft) right-hand breakdown shoulder so that disabled vehicles can be safely parked without obstructing the travel lanes. A 0.6 m (2 ft) lateral barrier offset is provided on the other side. This design is less safe because it reduces emergency maneuvering room and requires violators and disabled vehicles in the left lane to merge across traffic to reach the shoulder. The minimum cross section should be used as an interim project or over short distances and increased enforcement along with incident management programs should be implemented to successfully operate the facility.



Contraflow HOV lanes utilize surplus roadway capacity in the off-peak direction of travel to satisfy excess demand in the peak direction. Most contraflow facilities in freeway settings are designed with moveable concrete barriers to separate opposing traffic flows when the facility is in operation. A special "zipper truck" is used to move the barriers into position between peak traffic periods.



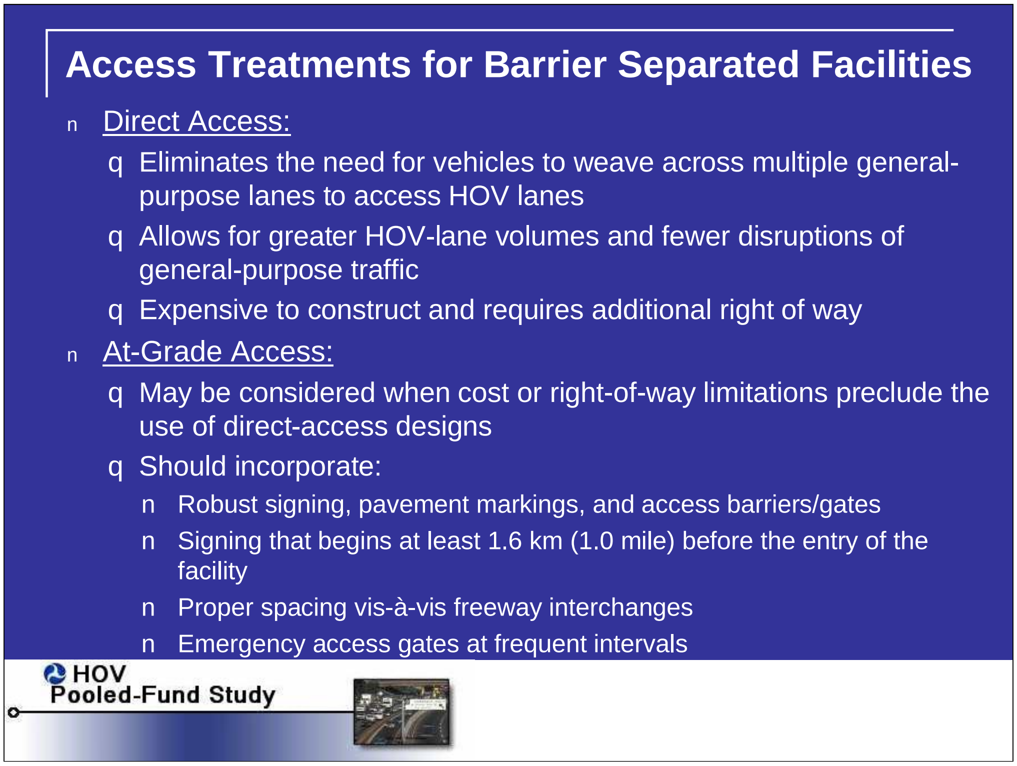
Due to the additional space needed to safely accommodate the moveable barrier, the desirable width of the contraflow lane and the lane adjacent to it is larger than normal. Desirable lane widths are 4.0 m (13 ft) during operation and 4.3 m (14 ft) during non-operation. The desirable shoulder width is 3.6 m (12 ft) when the facility is operating and 3.0 m (10 ft) when it is not. The minimum cross section includes 2.4 m (8 ft) shoulder widths and 4.0 m (13 ft) lane widths during non-operational periods. The minimum cross section during operational periods includes a 3.0 m (10 ft) shoulder and 3.6 m (12 ft) lane. Very few contraflow HOV lanes on arterial streets are currently in operation in the United States. Where these facilities have been implemented, they do not entail the use of moveable concrete barriers. The width of contraflow HOV lanes on arterial streets depends on the volume of pedestrian traffic adjacent to the lane. Standard lane widths range from a minimum of 3.3 m (11 ft) to 4.3 m (14 ft) in areas with significant pedestrian movements.



Several safety considerations should be accounted for in the access and enforcement design process for Contraflow lanes:

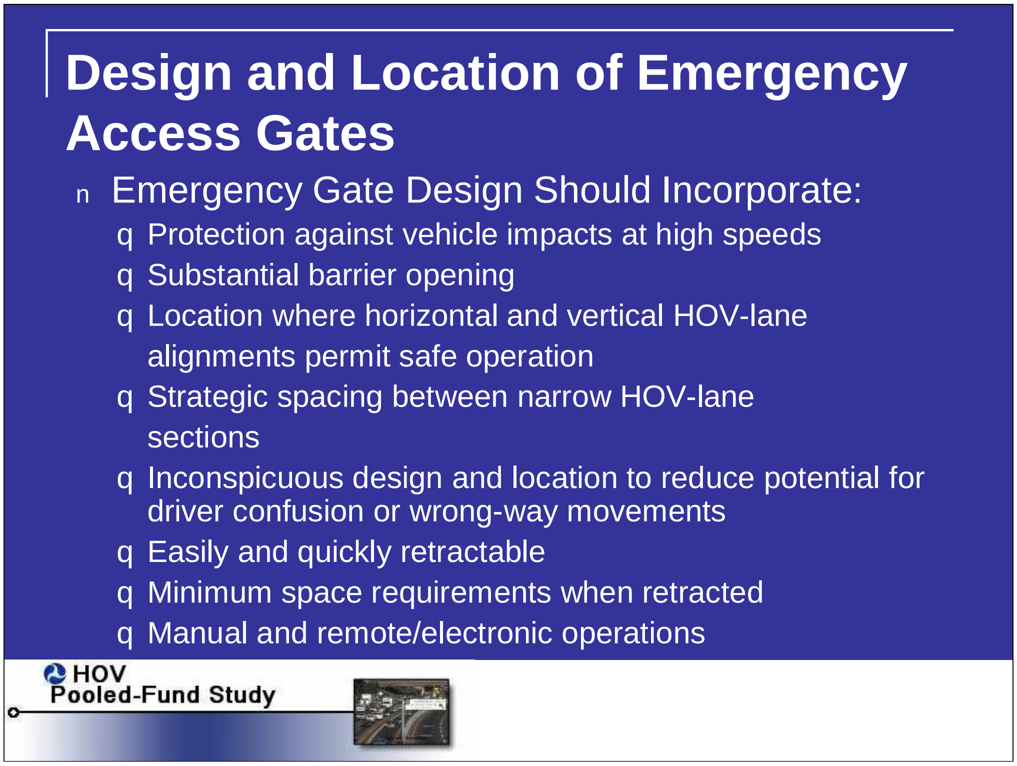
- Where possible, crossovers should be located where natural slowdowns occur, such as an approach to a central business district. This reduces high-speed weaving maneuvers and the disruption of traffic flow.
- When applicable, Advance signing in the peak and off-peak direction should indicate facility operations and oncoming traffic.
- MUTCD signing and physical gates/barriers that prevent wrong-way movements are particularly important on contraflow facilities, as motorists may not be familiar with the function of the facility or its operations schedule.
- Enforcement activities should occur in a designated zone at the entrance to the facility where officers can redirect ineligible users and motorists that may have inadvertently entered the lane. Adequate lane width (4.3 m [14 ft]) should be provided for enforcement activities at these sites.

Reversing the direction of traffic lane on a freeway or arterial street involves obvious safety considerations. These and other operational elements are examined in the following chapter. Design considerations associated with contraflow HOV lanes also have potential safety implications. A viable contraflow design typically requires at least a 60/40 directional split in peak/off-peak traffic. Corridors with more balanced traffic flows generally lack sufficient off-peak capacity to safely implement a contraflow lane. The danger of reducing off-peak capacity for contraflow-lane implementation is evidenced by higher crash rates in the off-peak direction as compared with the peak direction for some facilities.



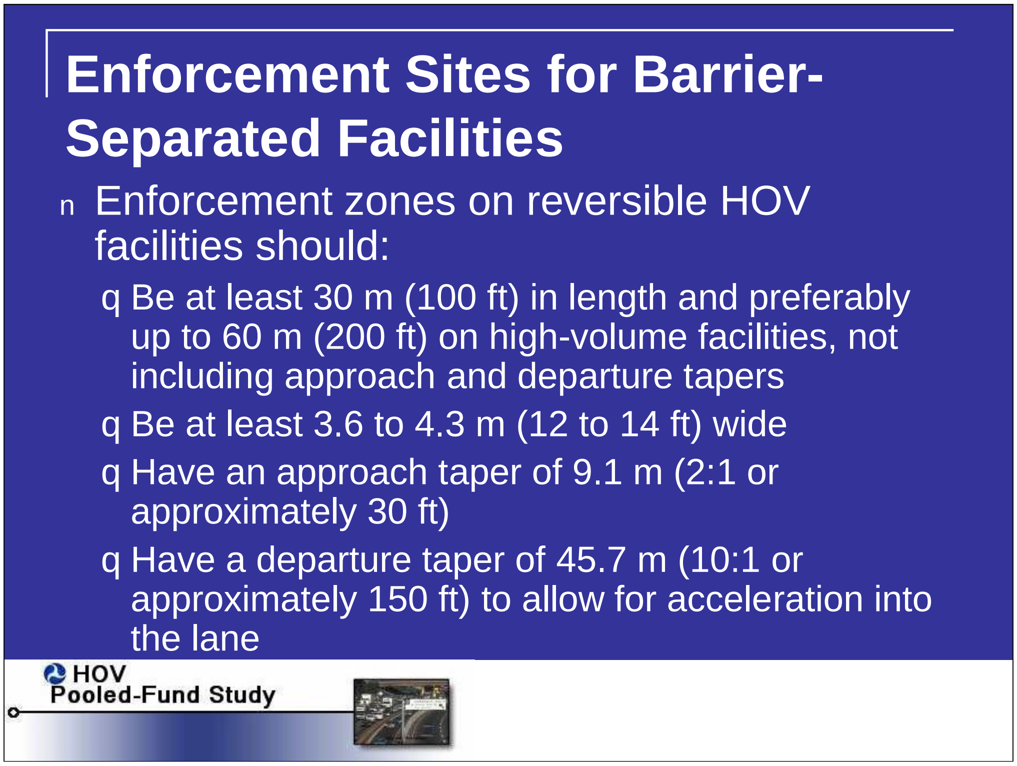
A number of direct and at-grade access treatments can be used with these facility types. The selection and design of access treatments involves consideration of various project factors. Flyover ramps and T-ramps are preferred for barrier-separated HOV lanes from a safety perspective. These direct-access options eliminate the need for vehicles to weave across multiple general-purpose lanes while rapidly accelerating or decelerating to access the HOV lane or exit the freeway. This allows for greater HOV-lane volumes and fewer disruptions of general-purpose traffic. However, direct-access treatments are expensive to construct and require additional right of way. At-grade access treatments may be considered when cost or right-of-way limitations preclude the use of direct-access designs. To improve safety and eliminate wrongway movements, at-grade access treatments should incorporate:

- Robust signing, pavement markings, and access barriers/gates
- Signing that begins at least 1.6 km (1.0 mile) before the entry of the facility and conforms to MUTCD and state/local guidelines
- Proper spacing vis-à-vis freeway interchanges so that vehicles have sufficient room to safely enter or exit the HOV facility and freeway
- Emergency access gates at frequent intervals so that disabled vehicles can be removed from the facility safely and quickly



The design and location of emergency access gates on barrier-separated HOV lanes involves consideration of safety. While these treatments are primarily intended to provide emergency access to tow trucks and first responders, they may also be used to provide an exit for HOV traffic trapped in a queue behind a disabled vehicle blocking the lane. Safe and effective emergency gate designs incorporate several features:

- Protection against vehicle impacts at high speeds
- Substantial barrier opening (usually 12.2 m [40 ft] or greater)
- Location where horizontal and vertical HOV-lane alignments permit safe operation
- Strategic spacing between narrow HOV-lane sections
- Inconspicuous design and location to reduce potential for driver confusion or wrong-way movements
- Easily and quickly retractable
- Minimum space requirements when retracted
- Manual and remote/electronic operations



The design of enforcement sites can impact the safety of barrier-separated HOV facilities for motorists and enforcement personnel alike. Poorly designed enforcement areas create driver confusion and unsafe conditions for officers trying to identify the number of occupants in passing vehicles. HOV enforcement without proper refuge areas can also disrupt traffic and lead to unsafe conditions on the HOV lane. Adequate lighting at ingress and egress points also enhances motorist and officer safety and facilitates vehicle-occupancy determination. The length of enforcement zones and storage areas depends on site-specific considerations such as the violation rate, traffic volume, enforcement presence, and vehicle mix. The following design guidelines apply to low-speed enforcement zones on reversible HOV facilities:

Be at least 30 m (100 ft) in length and preferably up to 60 m (200 ft) on high-volume facilities, not including approach and departure tapers

Be at least 3.6 to 4.3 m (12 to 14 ft) wide

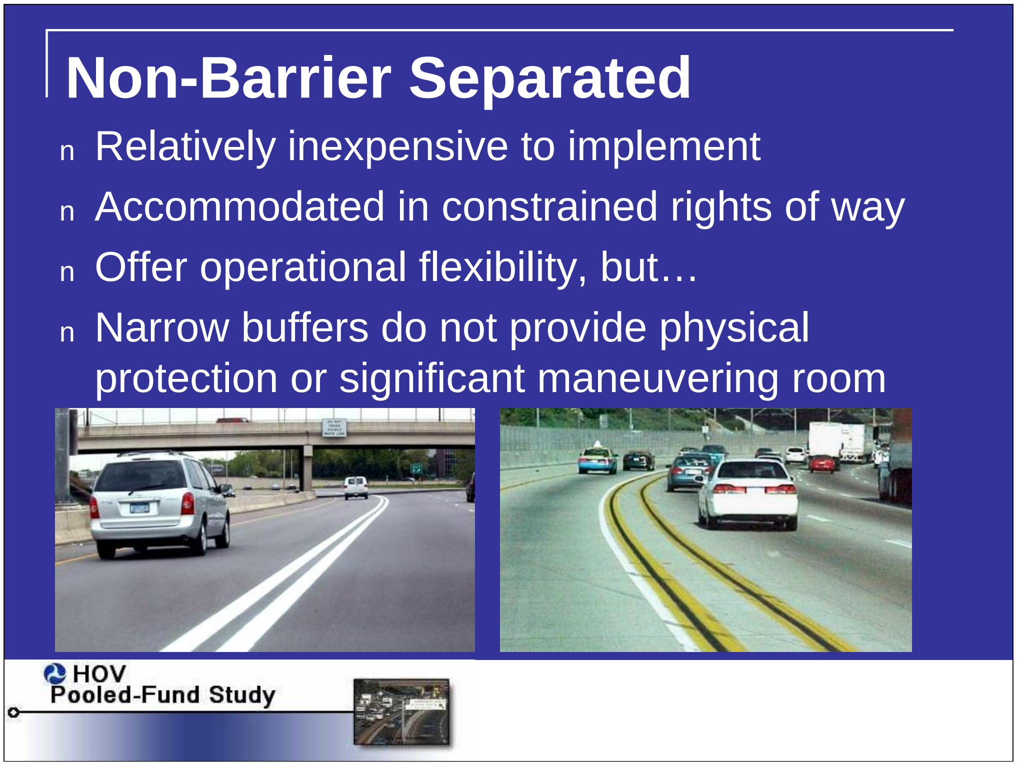
Have an approach taper of 9.1 m (2:1 or approximately 30 ft)

Have a departure taper of 45.7 m (10:1 or approximately 150 ft) to allow for acceleration into the lane

Geometric Design: Non-Barrier-Separated Facilities

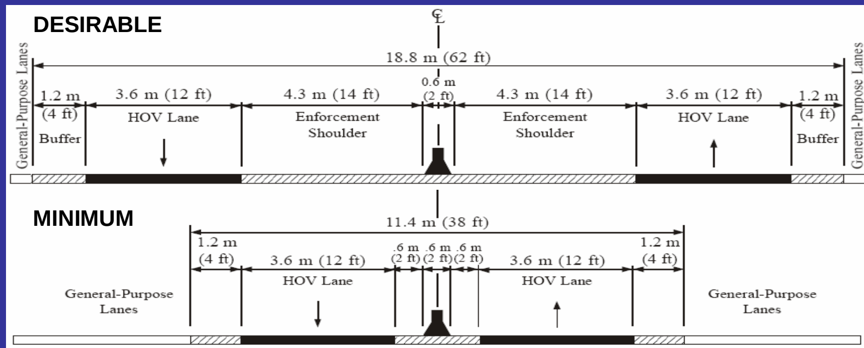
Safety Considerations

HOV
Pooled-Fund Study



Even though non-barrier separated HOV facilities are generally considered less safe than barrier-separated facilities, there are some advantages in non-barrier designs. First, non-barrier facilities are significantly less expensive because they can be implemented by adding a lane without having to provide additional width for a barrier. General purpose lanes can be converted to HOV lanes with relative ease, so long as the conversion of the lane is not detrimental to general traffic flow. Non-barrier separated HOV lanes can be implemented in constrained rights-of-way that do not allow for the construction of barrier-separated facilities. However, a disadvantage with non-barrier separated lanes is that they do not provide physical protection or significant maneuvering room if evasive action is required. Wider buffers between the HOV lanes and general-purpose lanes enhance maneuvering room but may create additional safety issues if they are inadvertently used as a breakdown area or passing lane.

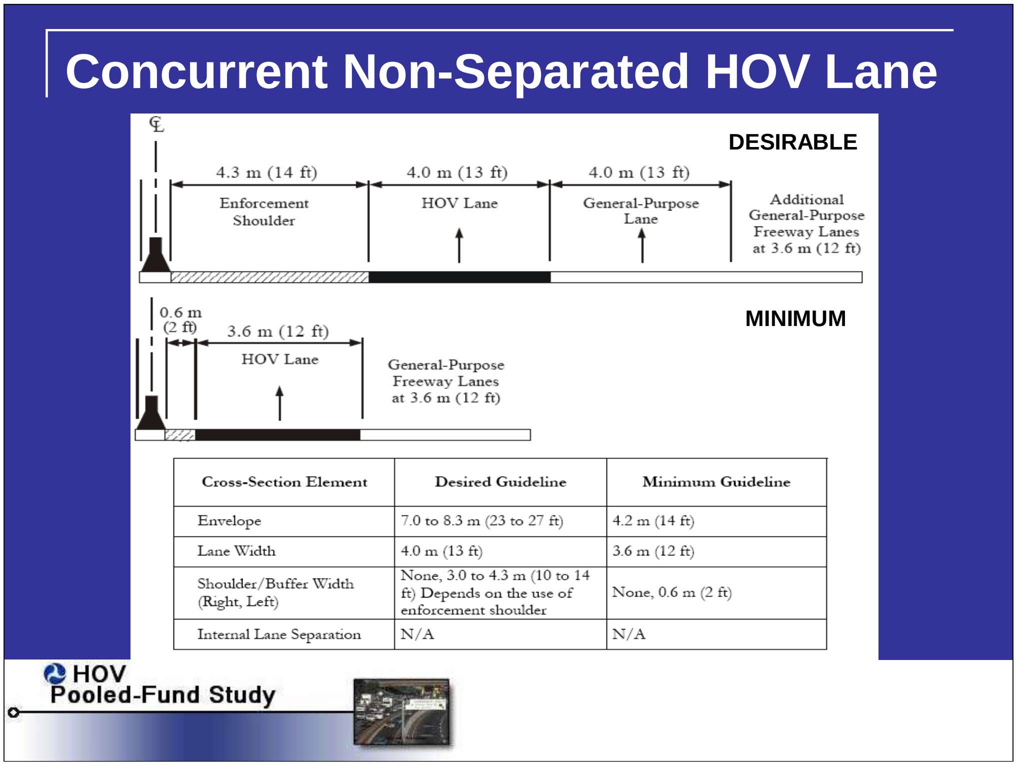
Concurrent Buffer-Separated HOV Lanes



Cross-Section Element	Desired Guideline	Minimum Guideline
Envelope	16.2 to 18.8 m (54 to 62 ft)	11.4 m (38 ft)
Lane Width	3.6 m (12 ft) per lane	3.6 m (12 ft) per lane
Shoulder/Buffer Width (Right, Left)	1.2 m (4 ft), 3.0 to 4.3 m (10 to 14 ft) per direction. Depends on the use of enforcement shoulder	1.2 m (4 ft), 0.6 m (2 ft) per direction
Internal Lane Separation	0.6 m (2 ft) barrier between lanes	0.6 m (2 ft) barrier between lanes

HOV Pooled-Fund Study

Concurrent buffer-separated facilities are freeway HOV lanes that offer a priority lane of travel in the same direction as the general-purpose lanes. They are typically constructed using the inside shoulder or median of the freeway right of way, and are separated from general-purpose lanes by a painted buffer. Cross-section designs for this type of facility are illustrated in the two cross section. The desirable envelope for two-way operations is 16.2 to 18.8 m (54 to 62 ft). The minimum envelope is 11.4 m (38 ft). Standard lane and buffer widths are 3.6 m (12 ft) and 1.2 m (4 ft), respectively. Shoulder widths of 3.0 to 4.3 m (10 to 14 ft) are desirable, depending on whether a regular or enforcement shoulder is provided. Enforcement personnel should be consulted to determine how and where they intend to identify and issue citations to violators because this will affect the design. Operational treatments should be incorporated if the minimum design cross section is used. The minimum cross section should be used as an interim project or over short distances. Increased enforcement and incident management programs should be implemented to successfully operate the facility. The designer must also consider the design exception requirements.



Cross-Section Element	Desired Guideline	Minimum Guideline
Envelope	7.0 to 8.3 m (23 to 27 ft)	4.2 m (14 ft)
Lane Width	4.0 m (13 ft)	3.6 m (12 ft)
Shoulder/Buffer Width (Right, Left)	None, 3.0 to 4.3 m (10 to 14 ft) Depends on the use of enforcement shoulder	None, 0.6 m (2 ft)
Internal Lane Separation	N/A	N/A

Concurrent non-separated HOV lanes often revert back to general-purpose use during off-peak periods. For this reason, they do not usually incorporate a buffer between the HOV facility and general-purpose lanes. Desirable and minimum designs for concurrent non-separated facilities on freeways are illustrated in the schematic. The desirable width of the HOV lane and the adjacent general-purpose lane is 4.0 m (13 ft). The added 0.3 m (1 ft) of lane width in the facility design is a safety measure to compensate for the lack of a buffer. Minimum lane width for freeway applications is 3.6 m (12 ft), with a 0.6 m (2 ft) lateral offset from the median barrier used instead of a shoulder.

Safety Considerations in Design of Arterial-Street HOV Lanes

Potential Safety Concerns	Techniques to Address
Turning movements at intersections	• Restrict turns by general-purpose vehicles during HOV operating hours • Allow turns by general-purpose vehicles at selected intersections only
Turning movements at driveways	• Restrict turns by general-purpose vehicles during HOV operating hours • Limit access points to adjacent land uses during HOV operating hours • Provide alternative access points for general-purpose vehicles
On-street parking	• Restrict on-street parking during HOV operating hours • Provide alternate parking spaces
On-street delivery vehicles	• Restrict on-street delivery vehicles during HOV operating hours • Provide alternate locations for delivery vehicles and allow access during non-operating hours
Pedestrian conflicts	• Provide well-marked crosswalks at intersections • Set signal timing to provide adequate pedestrian crossing time • Provide center median waiting area if needed • Take special measures, such as reducing speed limits in school, hospital, and other zones
Bicycle conflicts	• Provide bicycle lane in areas with high bicycle volumes

HOV Pooled-Fund Study

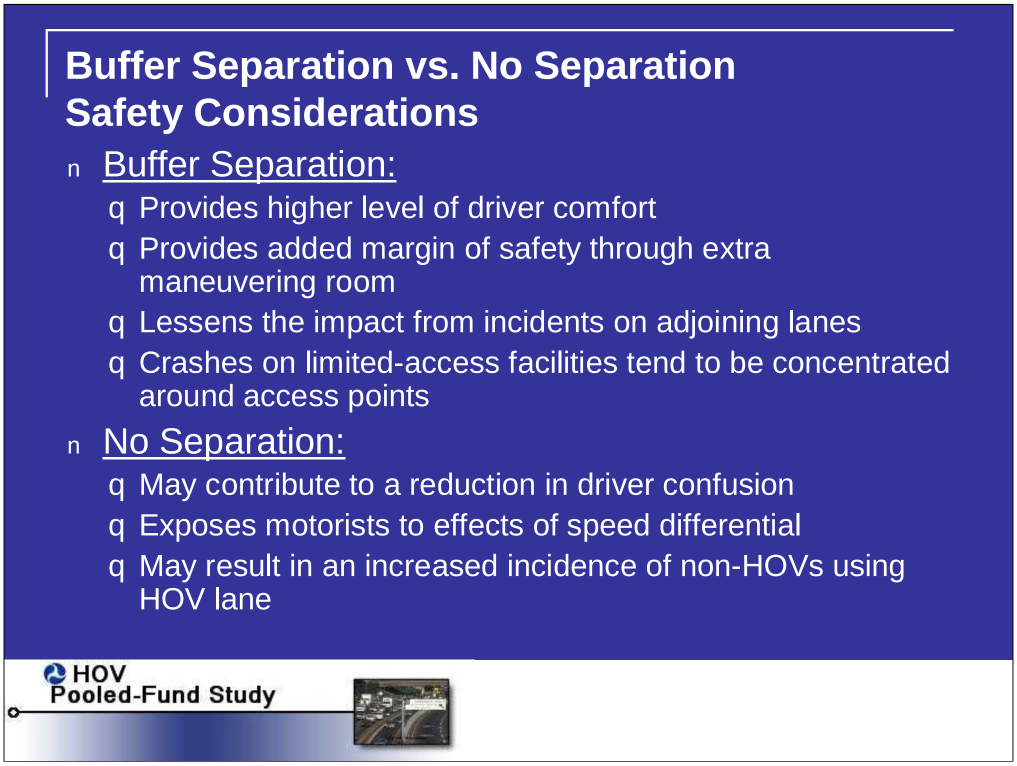
This table summarizes potential design and operational safety concerns that may arise on arterial-street HOV lanes and identifies possible approaches for addressing them. An arterial-street HOV facility is essentially a concurrent non-separated HOV lane in an arterial-street environment. Various facility cross sections and treatments have been implemented and the safety considerations associated with them are diverse. Warning signs, top-of-curb markings, pavement markings, and pedestrian fencing are common design techniques used to alert motorists, pedestrians, and bicyclists to these conflicts. “Restricted lane ahead” signs should be placed well in advance of arterial HOV lanes to allow general traffic to safely transition into another lane. Special attention should be paid to pavement surfaces on arterial HOV lanes that accommodate bicyclists. These surfaces should be smooth and free of potholes and ruts, and the facility should be regularly swept to clear debris. Potential obstacles such as raised pavement markers, drainage grates, and manhole covers that may cause unexpected maneuvers by bicyclists should be removed, relocated, or more clearly marked. This table summarizes other potential design and operational safety concerns that may arise on arterial-street HOV lanes and identifies possible approaches for addressing them.

Access Treatments for Non-Barrier-Separated HOV Facilities

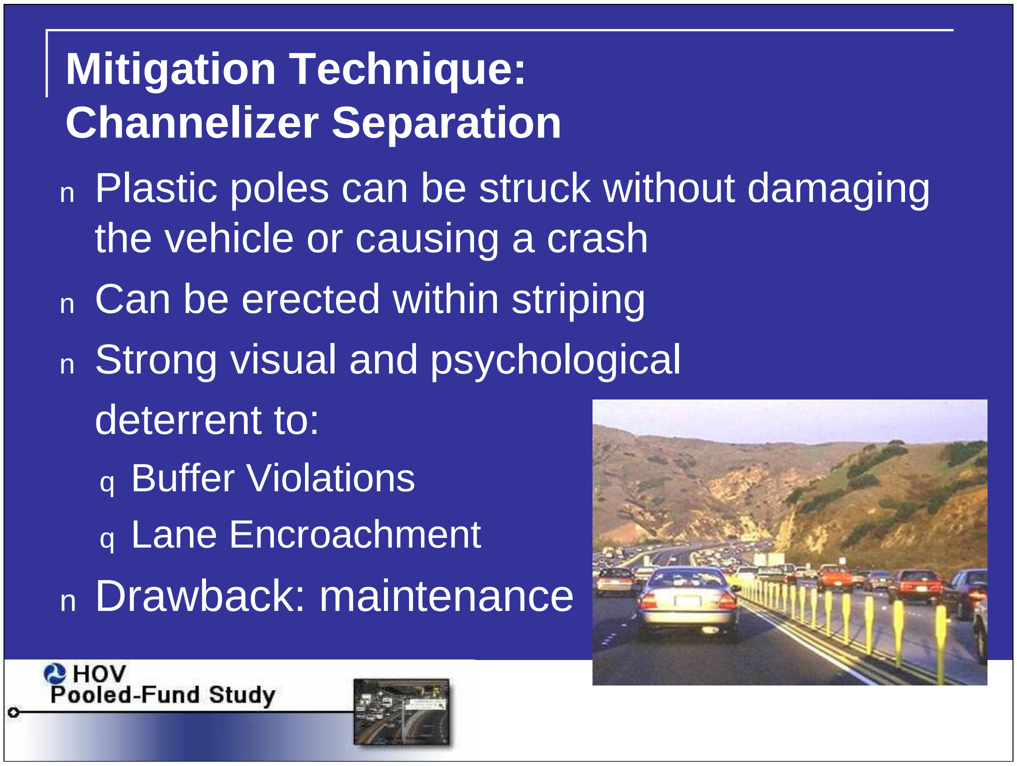
- **Limited (restricted)**
  - No weave, acceleration, or deceleration lane
  - Conspicuous signing and pavement markings are utilized to avoid driver confusion regarding lane designation
- **Unlimited (contiguous)**
  - Acceleration, deceleration, or weave lanes may be provided
  - Vertical alignment is considered when designing and locating individual access points
  - Advance signing is used to reduce abrupt and unexpected weaving maneuvers at access locations
  - Ingress/egress points are generally provided at freeway-to-freeway interchanges and at other locations that can safely accommodate merging and weaving

HOV
Pooled-Fund Study

Two access designs, limited (also called restricted) and unlimited (also called continuous or contiguous), are used with concurrent HOV lanes. Unlimited access is often employed on non-separated concurrent facilities that operate on a part-time basis. Because these facilities automatically switch between HOV operations and mixed use according to the time of day, restrictive access treatments are not typically used. Vehicles are allowed unimpeded movement to and from the HOV lane anywhere along its length. Limited-access treatments confine legal HOV ingress and egress maneuvers to specific locations. A buffer or barrier is used to separate the HOV facility from the adjacent general-purpose lane between access points. Separate ingresses and egresses points may be provided or a single access opening may serve both purposes.



Buffer-separated and non-separated HOV facilities are relatively inexpensive to implement, can be accommodated in constrained rights of way, and offer operational flexibility. However, their use implies unique safety considerations. Some researchers assert that the traffic dynamics and design considerations of specific projects may cause buffer separation and limited ingress and egress treatments to be an advantage in some locations and a disadvantage in others. Crashes on limited-access buffer-separated facilities tend to be concentrated around ingress/egress points. Merging and weaving maneuvers are condensed to the vicinity of access points, causing a migration of congestion and crashes to these locations. Conversely, collisions on HOV lanes with continuous access are typically distributed more evenly along the length of the facility. Some practitioners have identified positive safety impacts of non-separated designs, such as a reduction in driver confusion with respect to the operation of part-time HOV facilities. However, the absence of designated access points on these facilities may degrade overall safety between adjacent traffic flows by allowing weaving and merging to occur at potentially hazardous locations, and exposing motorists to the effects of speed differentials. Safety issues may also arise as a result of an increased incidence of non HOVs using the HOV lane as a passing lane or vehicles in the HOV lane using the inside general-purpose lane to pass slower-moving HOVs where conditions permit. Although there is no consensus on whether the presence or absence of buffers an limited access has a systematic impact on facility safety, it is generally agreed that both buffer- and non-separated HOV lanes are less safe than barrier-separated designs.



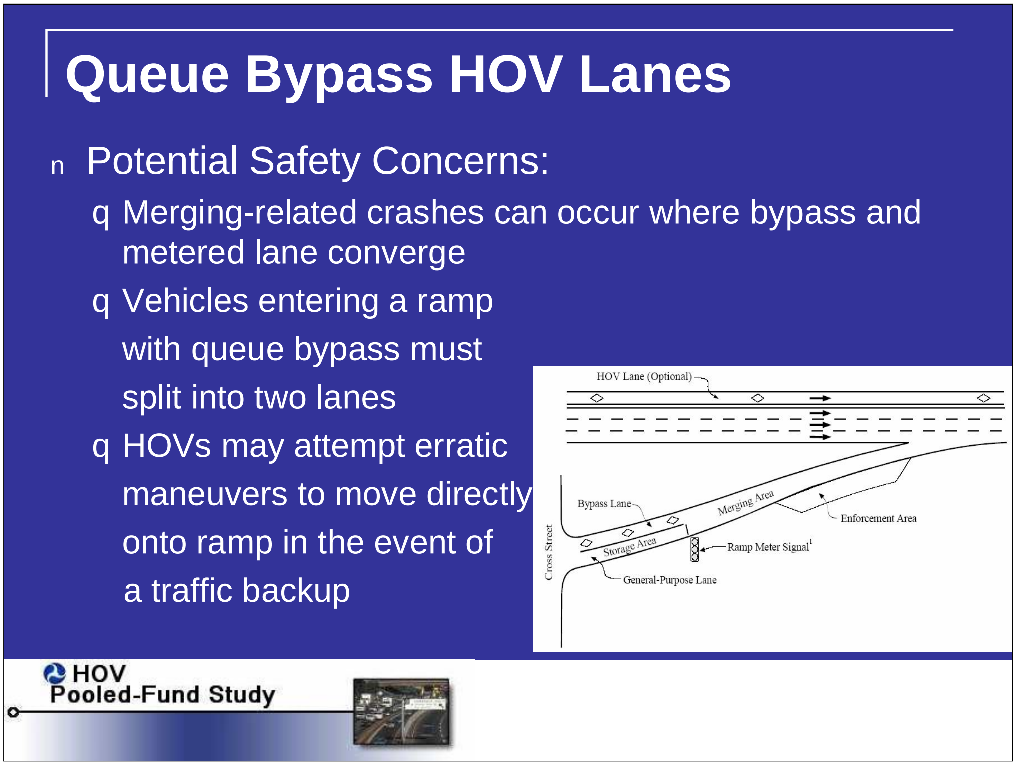
A possible design modification to improve the safety of substandard buffer-separated HOV lanes is retroflective tubular markers installed within the buffer striping. Although these plastic poles can be struck without causing damage to vehicles, they provide a strong visual and psychological barrier to buffer violations and lane encroachment, are a much less costly than concrete barriers, and can be accommodated in constrained rights-of-way. Tubular markers provide a sense of security for drivers in the HOV lane by lessening the likelihood that a slower-moving vehicle in an adjacent general-purpose lane will suddenly veer in front of them. The drawback to plastic channelizers is that they require a high degree of replacement.

Safety Impacts Associated With Wide Buffers

- Safety Advantages:
  - Greater separation of traffic flows and reduced exposure to speed differentials and erratic maneuvers
  - Improved driver comfort and incident isolation
  - Illegal access/buffer violation more obvious
  - Potential for incorporating wider and longer acceleration, deceleration, and weave lanes
- Safety Disadvantages:
  - Use of buffer as breakdown or refuge area
  - Use of buffer for passing

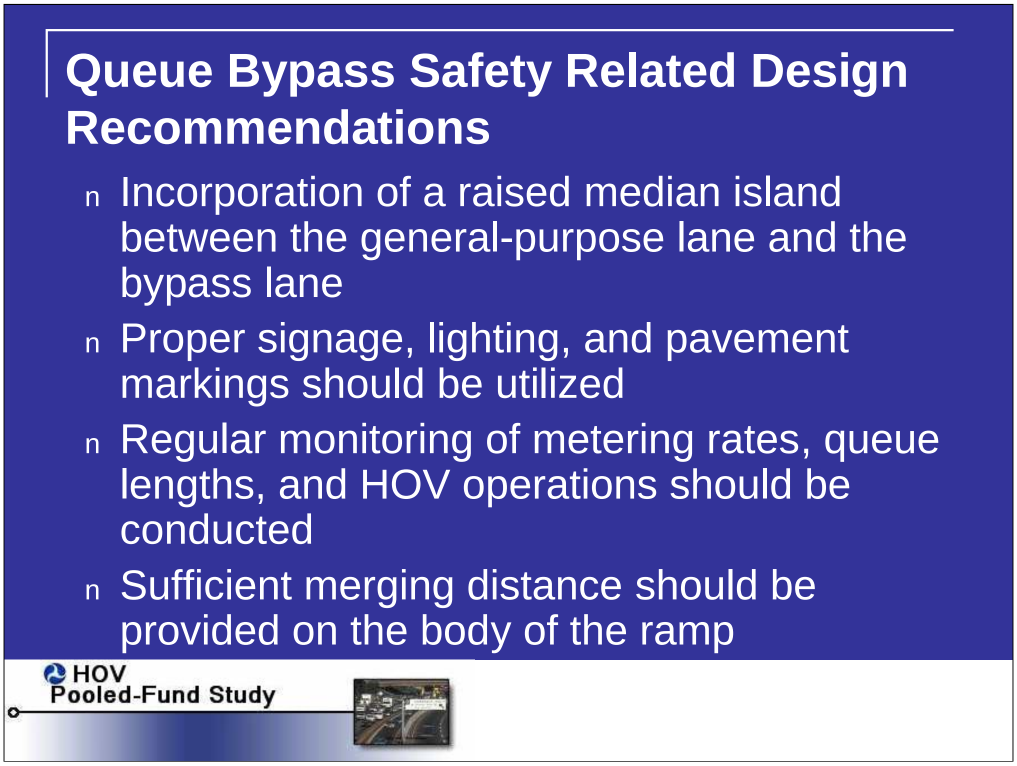
HOV
Pooled-Fund Study

A wide buffer does not physically prevent motorists from illegally entering or exiting an HOV lane. However, it may enhance safety by making it less likely that slow-moving vehicles in congested general-purpose lanes will suddenly veer into a fast-moving HOV lane or vice versa. Wide buffers also facilitate the provision of extended acceleration, deceleration, and weave lanes, which can enhance HOV safety by increasing storage capacity, reducing congestion at egress locations, smoothing merging activities at high-speed ingress points, and alleviating general access conflicts. Potential negative safety impacts of wide buffers over long distances include use of the buffer as a breakdown/refuge area or for passing. The use of appropriate striping and pavement markings can help counteract these problems. For concurrent HOV facilities, medium to wide buffers are generally used in conjunction with limited access.



Limited research has been conducted on the safety impact of HOV queue bypass facilities. One of the most common types of treatments is the ramp meter bypass. HOVs typically move through the metering signal without stopping, while vehicles in the metered lane must stop and queue. These lanes taper into one lane prior to merging with the freeway lanes. The provision of a queue bypass preserves travel time savings and trip reliability for high-occupancy traffic. However, there are several potential safety concerns associated with this type of treatment:

- A violator (or HOV) that finds itself in the metered general-purpose lane may create a vehicle conflict by attempting to change lanes into the faster HOV lane.
- Where the bypass and metered lanes converge after the metering signal, there is the potential for merging-related crashes to occur.
- Vehicles entering a ramp with a queue bypass must immediately split into two lanes. The unpredictable maneuvers sometimes brought about by this design may create a safety problem.
- If the metered queue extends back onto the surface street, HOVs may attempt erratic maneuvers to bypass this temporary delay and move directly onto the ramp and into the queue bypass lane.



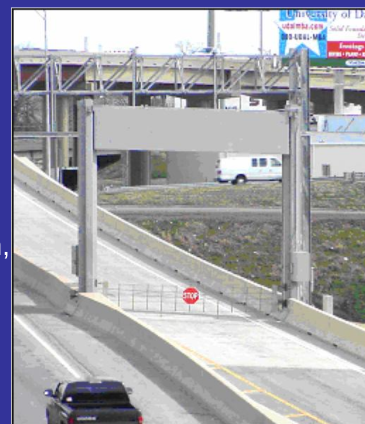
Consideration of safety issues in queue bypass design can prevent or alleviate some of the previous mentioned concerns:

- Incorporation of a raised median island between the general-purpose lane and the bypass lane imparts characteristics of an exclusive ramp to the bypass facility, improving safety by separating moving and stopped vehicles.
- If lane separation is not possible and the ramp has sufficient storage capacity, the HOV queue bypass should begin after the ramp entrance point. Though the single-lane ramp entrance may periodically delay HOVs, it should largely eliminate conflicts at ramp entrances.
- Proper signage, lighting, and pavement markings should be utilized to reduce erratic maneuvers prior to and on the ramp.
- Regular monitoring of metering rates, queue lengths, and HOV operations should be conducted to optimize the operation of the ramp and minimize unnecessary queue formation and traffic problems.
- Sufficient merging distance should be provided on the body of the ramp so that HOVs and general traffic can safely merge together and assume the same speeds prior to entering the freeway.

The design of the ramp meter bypass should be determined by safety considerations related to geometric, operational, and traffic demand conditions at each location. Consultation with local transit agencies, traffic engineering agencies, and traffic management center personnel is recommended when determining which side the HOV bypass will be located and whether or not the HOV bypass will be metered. On curved ramps, the HOV lane should generally be on the outside of the general lane (i.e., the lane having the larger radius). This gives the non-stop HOVs a lower degree of curvature, but more importantly, metered lane traffic has a clearer rear view of the HOV lane, thus reducing the hazard of their changing lanes8.

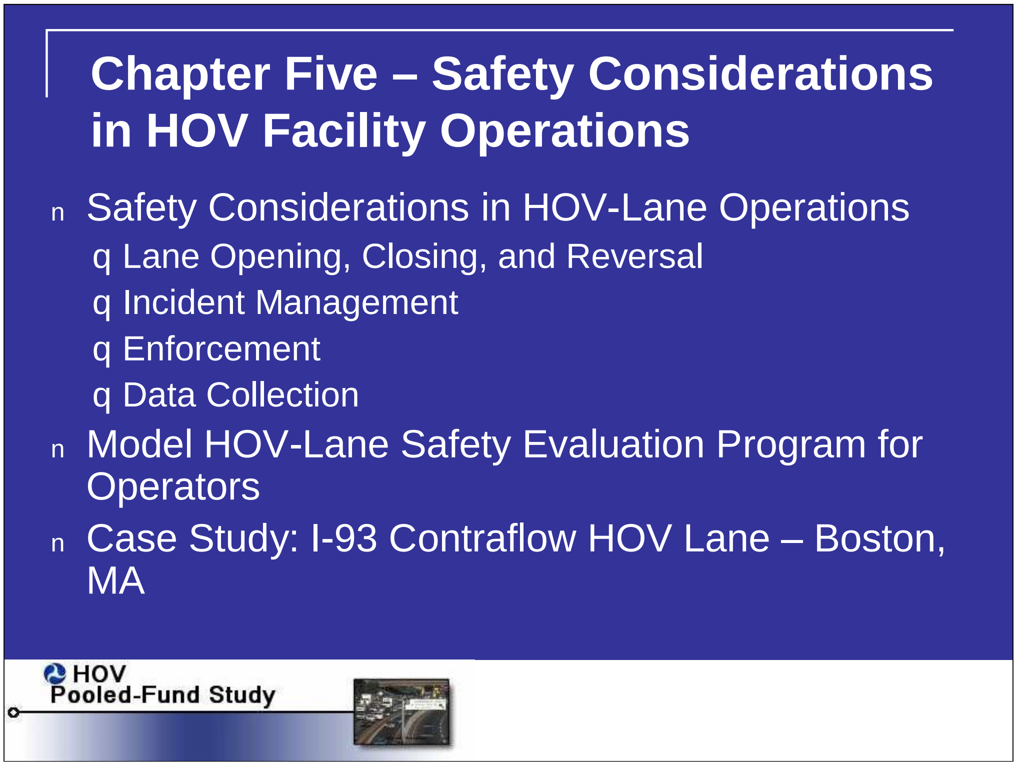
Case Study

- Vehicle-Arresting Barrier – Dallas, TX
  - Texas DOT Incorporated Vehicle-Arresting Barrier into design of reversible HOV-lane ramp
  - Designed to ensure that vehicles on freeway could not mistakenly enter facility in wrong direction
  - Several additional barriers have been installed at entrance ramps in Houston, other HOV lane operators have expressed interest

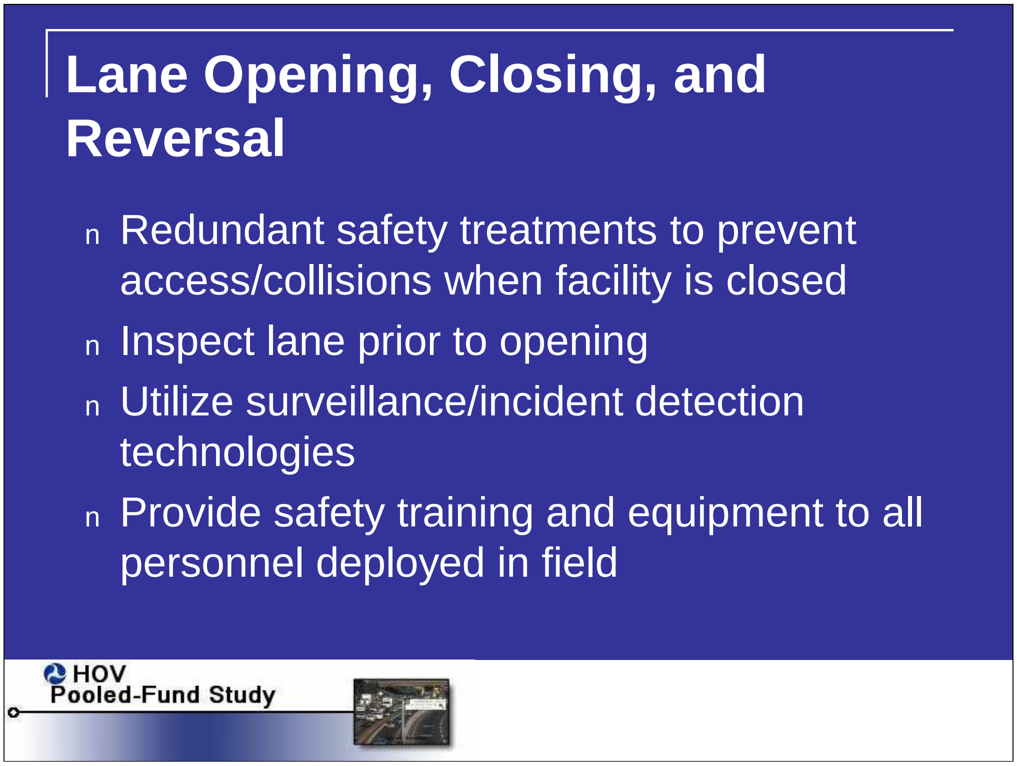


HOV Pooled-Fund Study

- Texas Department of Transportation decided to incorporate Vehicle Arresting Barrier into the design of one of the city’s reversible HOV-lane ramps.
- Designed to safely decelerate vehicles traveling at over 60mph, ensures that they do not enter the facility in the wrong direction resulting in potentially severe collisions.
- Installed in 2001; in 2005 several additional barriers were installed at entrance ramps to reversible HOV facilities in Houston.
- Other HOV lane operators have expressed interest in implementing these types of barriers to reduce fatalities, injuries, and litigation stemming from wrong-way movements on reversible facilities.



Chapter Five focuses on HOV-lane operations, describing safety considerations pertaining to stakeholder activities and examining operational issues relevant to specific types of HOV facilities. Safety considerations in daily operations are presented for topics such as lane opening, closing and reversal, incident management, enforcement and data collection. The chapter describes a model HOV-lane safety evaluation program, which can be used to assist facility operators in identifying and mitigating safety problems.



The manual placement, retrieval and operation of traffic control devices on an HOV facility is an activity that can expose crews to dangerous environments. Special safety considerations should be incorporated into HOV-lane operations to reduce the potential for injury to operations personnel and motorists. Redundant safety treatments such as additional signage, gates, beacons and barricades should be deployed to prevent motorists from inadvertently attempting to access the lane when it is closed. The HOV lane should be inspected prior to opening to ensure that it is free of debris and obstructions, and all traffic control devices are properly functioning. Surveillance technologies should be utilized for incident detection and to confirm the operation of manually operated traffic control devices. The facility operations supervisor should be authorized to prevent the HOV-lane from opening if the facility cannot be safely operated. Adequate safety training and equipment should be provided to all personnel deployed in the field.

Incident Management

Table 2-1. Potential Incident Response Stakeholders and Strategies

Incident	Potential Response Strategies
Disabled vehicle (flat tire, run out of gas, etc.)	• Commercial towing service • Police
Disabled bus	• Transit operator tow truck and replacement bus • Commercial towing services • Police to manage traffic
Crash/no injuries	• Police • Commercial towing service
Crash/injuries	• Emergency medical services (EMS), ambulance • Police • Commercial towing service
Crash/special problems (toxic substance, etc.) or hazardous waste	• Police • Commercial towing service • Fire, EMS, or other special response team
Facility damage and/or debris	• Emergency maintenance repairs
Snow, ice, flooding, or other weather-related emergency	• Snow plows and other service vehicles • Commercial towing service

HOV Pooled-Fund Study

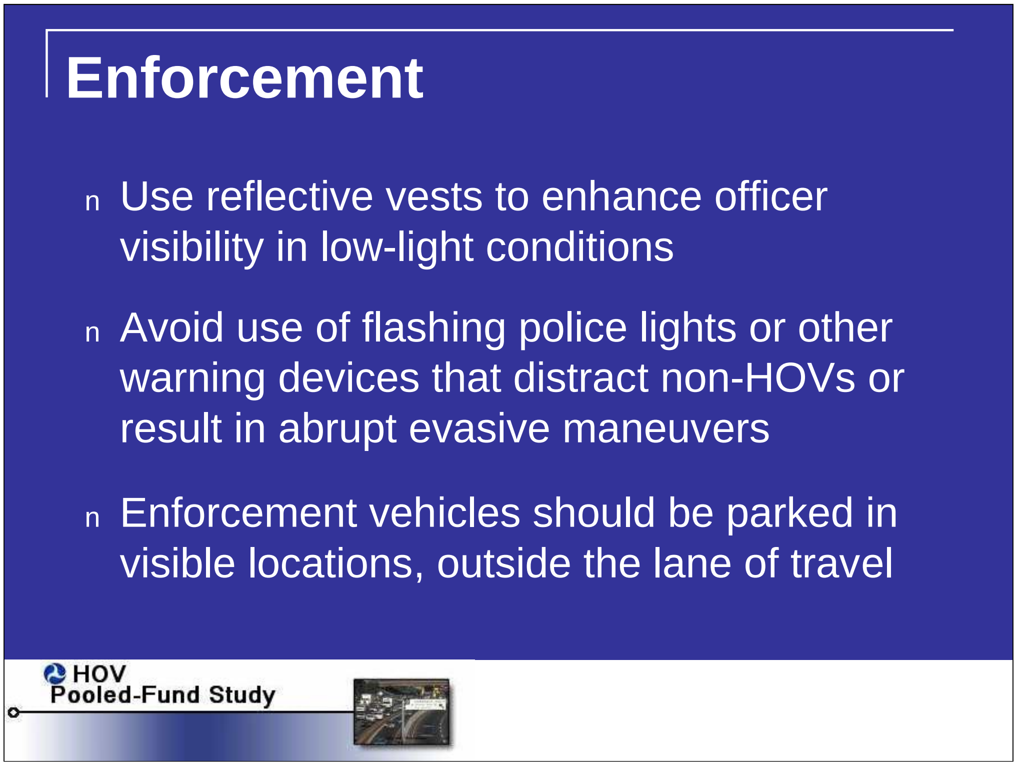
Incident management is the coordinated use of personnel and resources to reduce the duration and impact of traffic incidents and improve the safety of motorists, crash victims, and responders. This table presents possible stakeholders response strategies for common HOV-lane incidents. The most common incident faced on an HOV facility is a disabled/damaged vehicle or multi-vehicle accident, but numerous other incidents like road debris or severe weather conditions may need to be handled as well. The stakeholders most likely to respond to these incidents include the police, emergency medical services, and tow services or other service vehicles. Through effective use of incident management on HOV lanes, initial events can be quickly addressed and secondary incidents can be prevented. Primary site management responsibilities include assessing the incident, prioritizing response activities, and notifying the appropriate stakeholders. Incident clearance may involve various entities and activities and, depending on the nature of the incident, may require temporary closure of the HOV facility. VMS signs and other methods of communication should be fully leveraged to promptly advise and update motorists regarding the location and status of the incident.

Access Treatments for Non-Barrier-Separated HOV Facilities

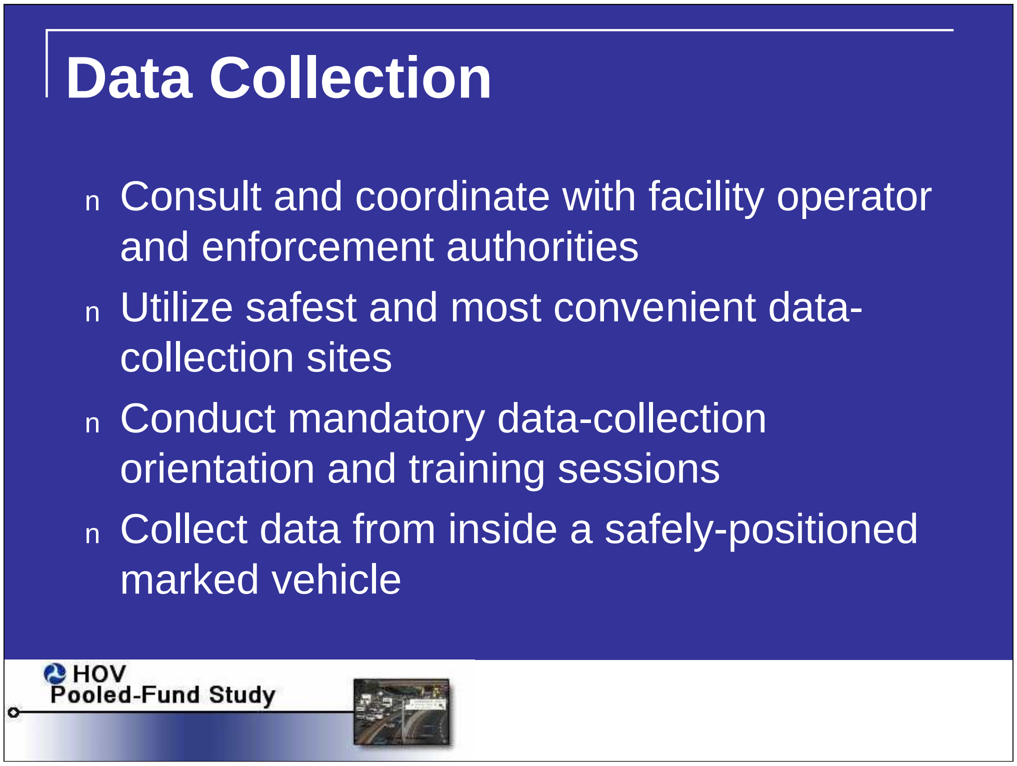
- **Limited (restricted)**
  - No weave, acceleration, or deceleration lane
  - Conspicuous signing and pavement markings are utilized to avoid driver confusion regarding lane designation
- **Unlimited (contiguous)**
  - Acceleration, deceleration, or weave lanes may be provided if available right-of-way exists
  - Vertical alignment and corresponding acceleration and deceleration requirements are taken into consideration when designing and locating individual access points
  - Advance signing is used to reduce abrupt and unexpected weaving maneuvers at access locations
  - Ingress/egress points are generally provided at freeway-to-freeway interchanges and at other locations that can safely accommodate merging and weaving

HOV
Pooled-Fund Study

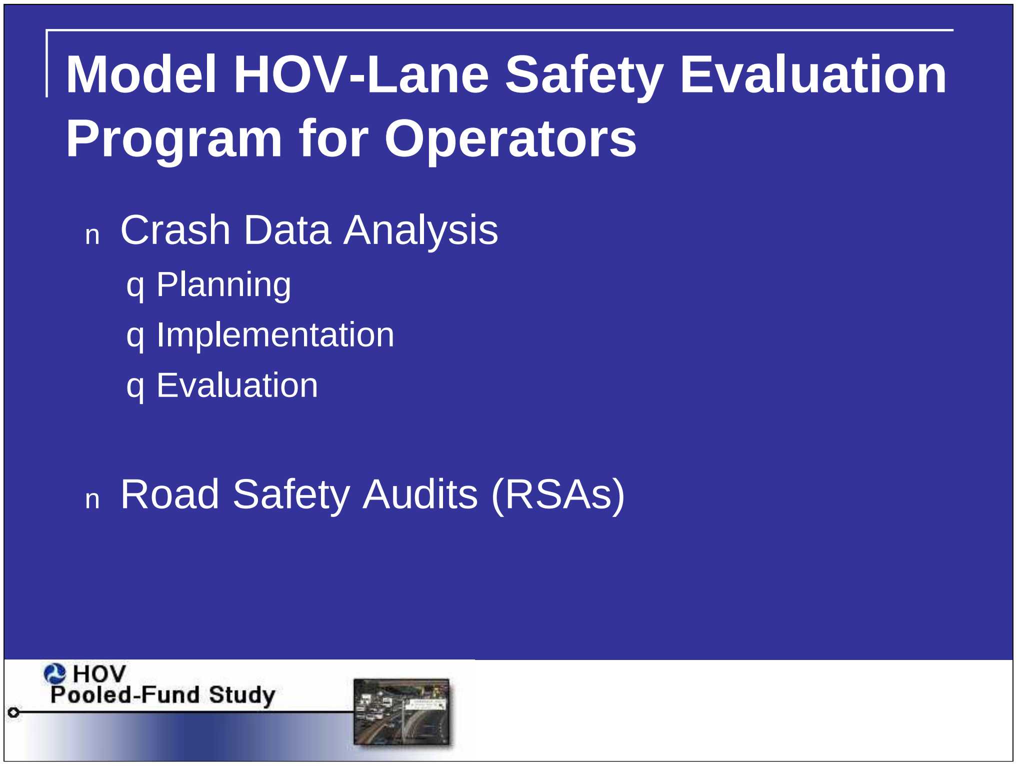
Two access designs, limited (also called restricted) and unlimited (also called continuous or contiguous), are used with concurrent HOV lanes. Unlimited access is often employed on non-separated concurrent facilities that operate on a part-time basis. Because these facilities automatically switch between HOV operations and mixed use according to the time of day, restrictive access treatments are not typically used. Vehicles are allowed unimpeded movement to and from the HOV lane anywhere along its length. Limited-access treatments confine legal HOV ingress and egress maneuvers to specific locations. A buffer or barrier is used to separate the HOV facility from the adjacent general-purpose lane between access points. Separate ingresses and egresses points may be provided or a single access opening may serve both purposes.



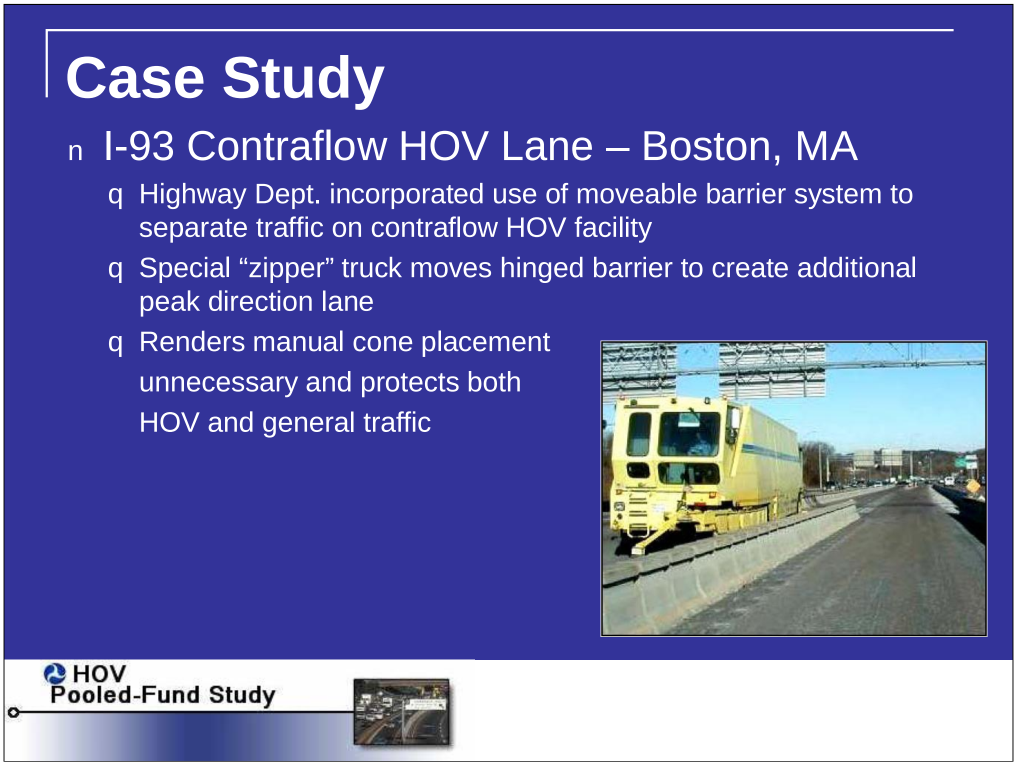
Enforcement is an essential component of HOV-lane operations and can affect facility safety. Among the safety issues associated with HOV-lane enforcement, preventing officer injury is the foremost consideration. The need for officers to position themselves next to moving traffic to determine vehicle occupancy creates the potential for vehicle-officer crashes. Speed limits in active enforcement zones should be reduced through the use of variable traffic control devices. Enforcement officers should wear reflective vests to enhance their visibility, especially in low-light conditions. The use of flashing police lights or enforcement beacons that may distract drivers in adjacent lanes or cause abrupt evasive maneuvers should be avoided. Enforcement vehicles should be safely parked outside the lane of travel, in a manner that protects the officer from errant vehicles.



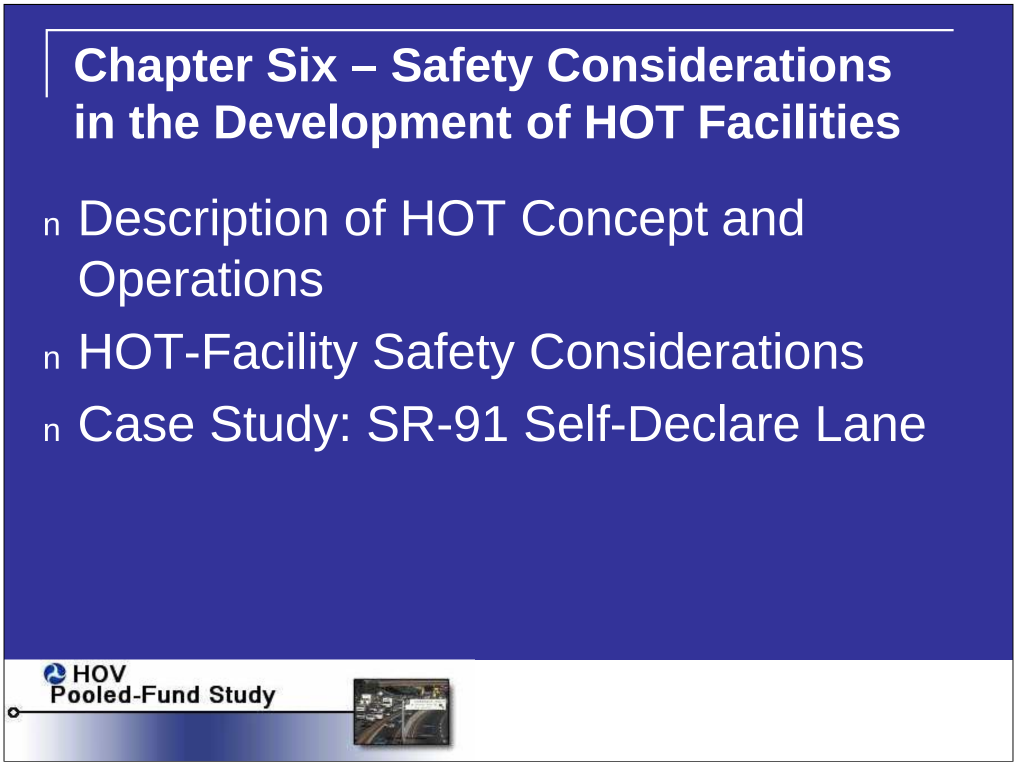
Data collection is an important component of HOV-lane operations because is enables facility operators and other stakeholders to gauge the success of the facility and identify weaknesses. Safety issues associated with the collection of HOV-lane data are similar to those encountered by enforcement personnel. In order to enhance the safety of data-collection initiatives, they should be coordinated with the facility operator and enforcement authorities. The safest and most convenient site for data-collection should be chosen. Orientation and training sessions that include thorough reviews of safety procedures and precautions should be mandatory prior to data-collection activities. Data should be collected from inside a marked vehicle that is positioned safely outside the lane of travel.



Evaluating the safety of an HOV lane is a process that has traditionally been undertaken by the operating agency or a project stakeholder following development of the facility. The HOV-lane performance monitoring process entails the collection and analysis of "before" and "after" safety data and the reporting of results. This process may be augmented by independent safety assessments called road safety audits. Provided adequate data collection has been planned for and undertaken, crash reports and data can typically be used to calculate crash rates before and after HOV lane implementation. If there is a significant difference in the pattern of crashes before and after the facility was implemented, these differences may be attributable to the HOV lane. A model HOV-safety evaluation program should incorporate planning, implementation and evaluation components. The planning component dictates which safety improvements are implemented and evaluated. During implementation, specific projects are assessed with respect to their feasibility and priority and subsequently designed and constructed. The evaluation process consist of a feedback loop in which data on post-construction safety performance is gathered, problems are identified and ranked, and additional improvements or countermeasures are developed. RSAs are formal examinations that are conducted to identify potential safety risks associated with the facility and ensure that measures to eliminate or reduce them are fully considered by the project management team.



- Massachusetts Highway Department incorporated the use of a moveable barrier system to separate traffic on the I-93 contraflow HOV facility.
- A special “zipper” truck moves hinged barrier to create additional peak direction lane; renders manual cone placement unnecessary and protects both HOV and general traffic.
- The barrier-separated contraflow facility is safer to enforce and collection of HOV data is safer through provision of a special control center at the facility.



HOT-facilities have some unique safety-related issues. The issues addressed in this chapter supplement the HOV-lane safety information presented in previous chapters. In particular, enforcement and driver-related safety concerns arising from special vehicle-occupancy determination techniques and tolling practices are examined.

Description of HOT Concepts and Operations

- HOT: High Occupancy Toll facilities
- Allow drivers of vehicles that do not meet occupancy requirements to purchase access
- All tolls paid electronically
- Toll rates vary to control demand
- Almost all are separated by concrete barriers to prevent illegal entering and exiting

HOV
Pooled-Fund Study

HOT facilities are essentially HOV lanes that allow drivers of vehicles that do not meet occupancy requirements to purchase access. Like HOV lanes, HOT facilities are designed to improve person movement and provide reliable, free-flow traffic conditions to facility users. They offer free or priority status to transit and carpools, while promoting more efficient use of facility space by selling excess capacity to users that would otherwise be denied access. All tolls are paid electronically and the toll rate varies according to the level of traffic on the facility to prevent congestion. Through the combined use of vehicle-occupancy regulations and electronic tolling, vehicle and person throughput are increased and a high level of service is maintained.

HOT Facility Safety Considerations

- Preventing Enforcement Officer Distraction
  - Proper enforcement site design
  - Appropriate signage
  - Reduced enforcement zone speed limits
  - Use of toll transponder verification technologies
- Preventing Driver Confusion
  - Clear, concise signage in advance of facility access points
  - Public outreach and marketing campaigns

HOV
Pooled-Fund Study

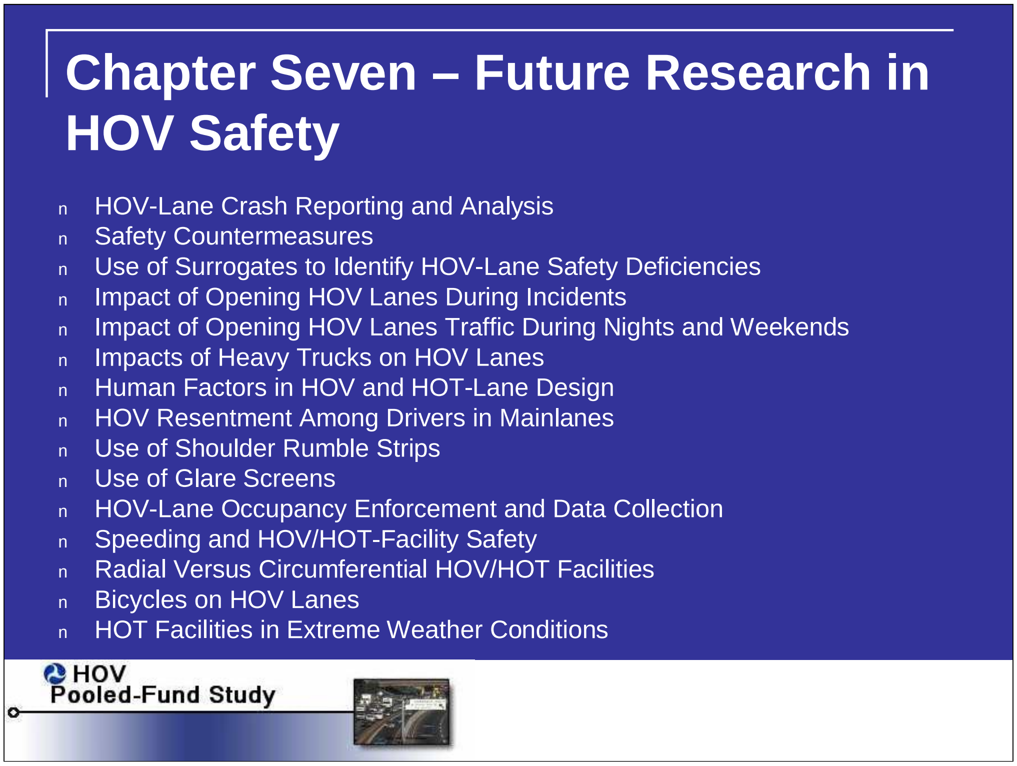
HOT-facility enforcement can be more involved than HOV-lane enforcement. In addition to determining the number of occupants traveling in vehicles, officers may be required to verify the presence and validity of toll transponders. While technology facilitates this task, potential safety issues may arise. Verification of transponder existence/validity and vehicle occupancy can lead to officer distraction and increase the potential for vehicle-pedestrian collisions. The safety impact of tasking officers with multiple verification responsibilities can be mitigated in a number of ways. These include: proper enforcement site design, appropriate signage, reduced enforcement zone speed limits, and use of advanced toll transponder verification technologies. In an attempt to prevent driver confusion when approaching a HOT facility, clear and concise signage should be displayed far ahead of facility access points so that drivers know what lane to be in, what the occupancy requirements are, and pricing. Public outreach and marketing campaigns can apprise motorists of facility regulations and operations, as well as common safety issues.

Case Study

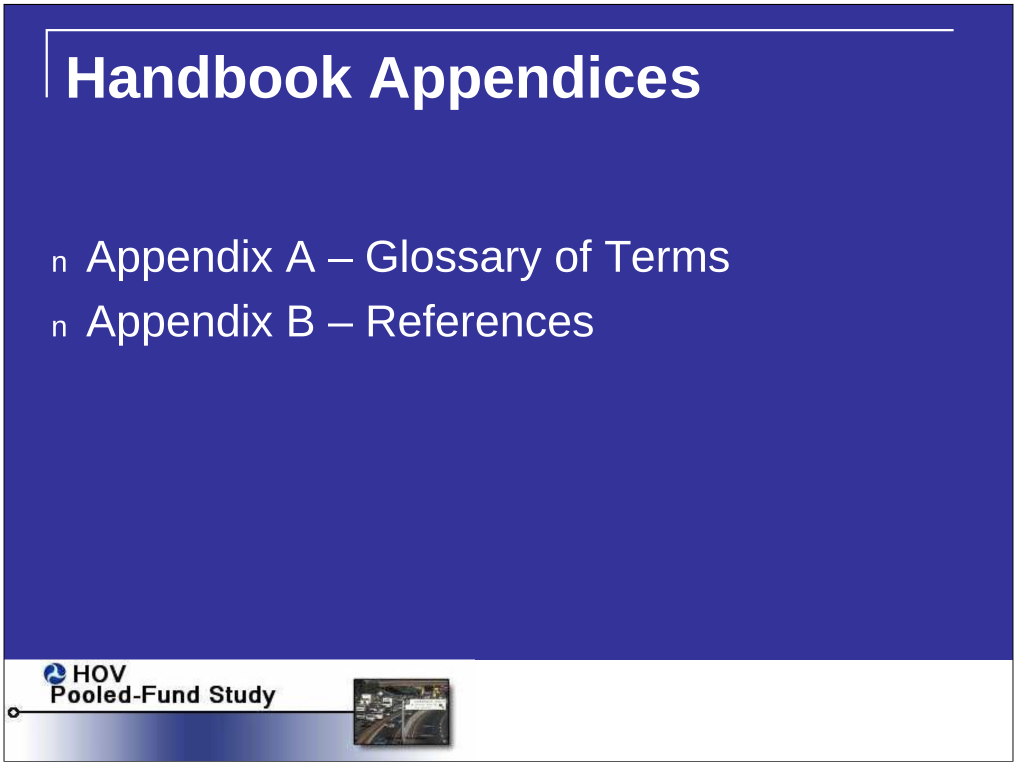
- SR-91 Self-Declare Lane – Anaheim, CA
  - SR-91 Express Lanes require that HOVs identify themselves
  - Safety issues associated with occupancy enforcement reduced
  - SR-91 enforcement agents concentrate on verifying occupancies in HOV3 3+ lane only
  - Additional benefits include reduced manual enforcement and related savings

HOV Pooled-Fund Study

- The SR-91 Express Lanes require that HOVs identify themselves which decreases safety issues associated with occupancy enforcement.
- SR-91 enforcement agents concentrate on verifying vehicle occupancies in HOV3+ lane only.
- Additional benefits include reduced manual enforcement requirements and related cost savings.



Chapter Seven describes potential topics for further study. The relationship between safety performance of HOV facilities and the numerous variables that can affect it is often poorly understood. Data and information required to draw conclusions regarding causative factors are sometimes incomplete or have not been collected. The objective of this chapter is to raise awareness of outstanding safety issues and study topics by highlighting various needs, gaps, and opportunities related to HOV and HOT safety research.



The appendices contain a glossary of terms and the references used in the handbook along with additional resources.

- Appendix A – Glossary of Terms

  Provides a glossary of commonly used terms associated with HOV-Lane Safety.

- Appendix B - References

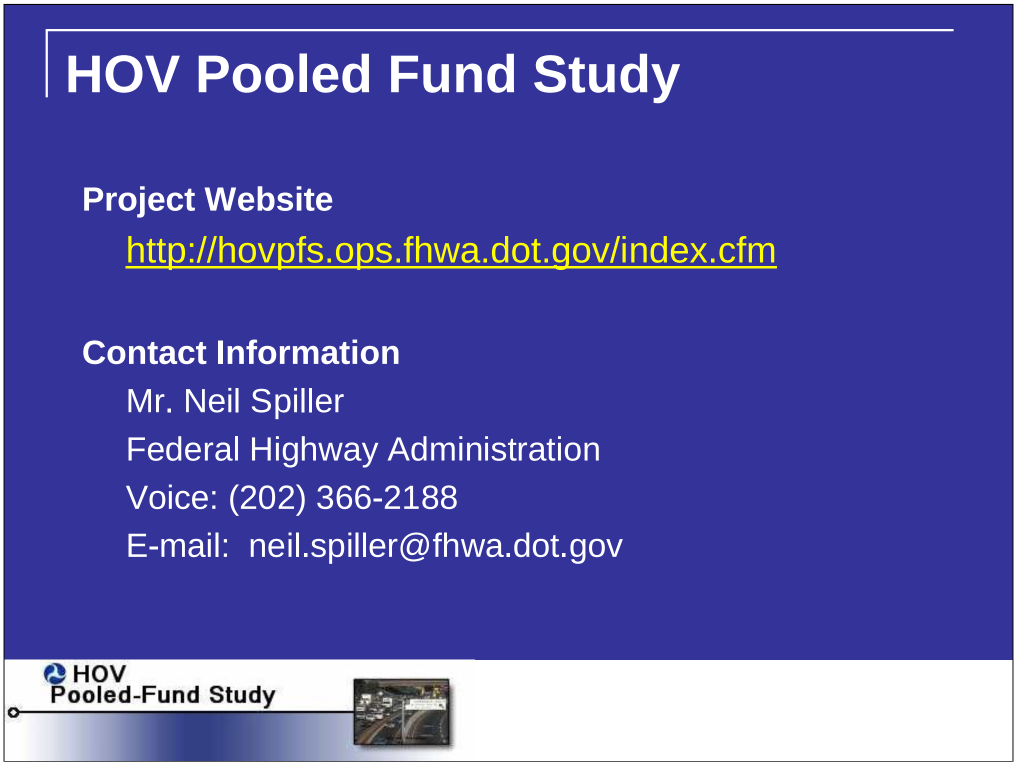
  Provides the references used in the handbook and additional resources.

Other HOV Pooled Fund Study Projects

- HOV Lane HOV Lane Performance Monitoring, Evaluation, and Reporting Handbook
- HOV Eligibility Requirements and Operating Hours Handbook
- HOV Lane Enforcement Handbook
- HOV Inventory

HOV
Pooled-Fund Study

Other HOV pooled fund study projects are highlighted on this slide.



More information on HOV Pooled Fund Study projects, including the HOV Safety Considerations Handbook, can be obtained from the website shown on the slide or by contacting Neil Spiller at FHWA.